APPENDIX D

PAPERS SUBMITTED TO NPS FOR CONSIDERATION IN THE SEIS PROCESS

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SOCIETY OF AUTOMOTIVE ENGINEERS 2001 CLEAN SNOWMOBILE CHALLENGE

Copies of this report can be obtained from the National Park Service. Requests can be made to:

Planning
Grand Teton National Park
PO Drawer 170
Moose, WY 83012

Summary

A final report entitled *The Society of Automotive Engineers Clean Snowmobile Challenge 2001* (August 2001)[2] was made available to NPS. The Clean Snowmobile Challenge invites intercollegiate participation under sponsorship by a number of local, state and federal agencies and private concerns. The stated goal of the competition is to encourage development of a snowmobile with improved emission and noise characteristics that meets desired levels of performance. The second annual competition, held in Jackson, Wyoming (as was the first), was won by the University of Waterloo using a 2-stroke snowmobile (Polaris Indy Trail) featuring catalytic after-treatment and a custom silencer. "The machine was successful at reducing noise and emissions while simultaneously improving fuel economy and maintaining adequate performance (report, page 1)."

[1] Cooperating County Liaison
[2] Prepared by Lori M. Fussell, Ph.D., Institute of Science, Ecology, and the Environment, Wilson WY

Those participating in the event competed against each other in the categories of emissions, fuel economy/range, noise, acceleration, handling, cold-start, hill climb, engineering design paper, oral presentation, cost minimization, and static display. Points were awarded to machines based on their performance in each of the events.

For the emissions portion of the competition, the overall winning snowmobile showed a 60% reduction in CO and a 63% reduction in combined HC and NOx. The highest point-getter was the University at Buffalo, SUNY, followed very closely by Kettering University, which achieved an 82% reduction in CO and a 97% reduction in HC+ NOx. Both of these entries were 4-stroke machines. In the noise test[3], the overall winner (Waterloo) produced a maximum sound level of 74 dB. This performance was equaled or bettered by four other entries including the high achievers in the emissions test. The University of Buffalo machine came in at a maximum 67 dB, and Kettering at 72. Optimizing on all test criteria, as stated, the University of Waterloo machine came out on top. However, Kettering was a very close second (less than 1 percentage point below), University at Buffalo was third (within 4 percentage points), and Minnesota State University was fourth (also within 4 percentage points). The University of Idaho was a close fifth.

It can be concluded that both 4-stroke and 2-stroke technologies are possible in reducing emissions and noise impacts. Further analysis is needed to look at a range of pollutant criteria.

2000-2001 Wyoming Snowmobile Survey

Copies of this report can be obtained from the State of Wyoming. Requests can be made to:

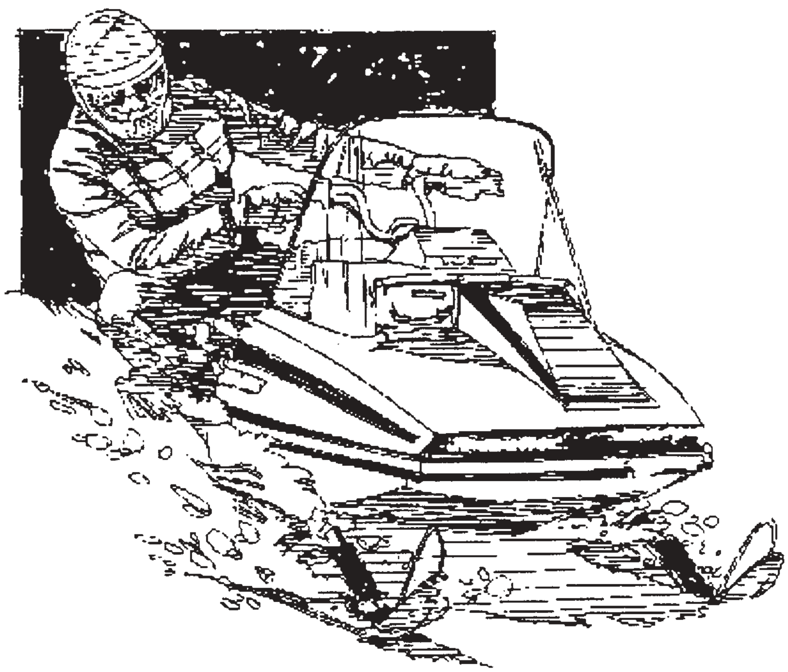
Kim Raap
Wyoming State Trail Coordinator
Herschler Building 1E
122 West 25th Street
Cheyenne, WY 82002

Executive Summary from the Report

The following pages are reproduced directly from the executive summary of the report.

[3] Using standard SAE testing procedures, tested a full throttle acceleration from 50 feet on both sides of the machine

RESULTS FROM 2000-2001 WYOMING SNOWMOBILE SURVEY: EXECUTIVE SUMMARY



Prepared for the Wyoming Department of State Parks and Historic Sites, Wyoming State Trails Program.

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Sponsored and Supported By:

The Wyoming Department of State Parks and Historic Sites,
The University of Wyoming,
And
The Wyoming State Snowmobile Association

October 2001

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WYOMING SNOWMOBILE EXECUTIVE SUMMARY

This report is a summary of the results from the 2000-2001 Wyoming Snowmobile survey. It combines the information from individual reports on three types of snowmobilers in Wyoming - nonresidents, residents and snowmobile outfitter clients. It is intended to illustrate the similarities and differences between Wyoming snowmobile trail user groups. Comprehensive, in-depth discussions of each of the groups can be found in their respective reports. However, this document is simply a combination and summary of these other reports to assist in comparisons between the Wyoming snowmobile trail users. The reader should consult the other individual reports for more detailed information on a specific snowmobile group.

Survey Results

General Season Information

Table 1 indicates that residents and nonresidents are generally more experienced snowmobilers than outfitter clients. Residents were expectedly the most experienced in Wyoming snowmobiling, averaging 15.1 years experience snowmobiling in Wyoming.

Table 1. Number of Years Snowmobiling

	Total Snowmobiling Years	WY Snowmobiling Years
Outfitter Clients	9.5	3.0
Resident	16.5	15.1
Nonresident	16.6	6.5

Table 2 shows that residents tend to own more snowmobiles than the other groups, averaging 2.6 snowmobiles per household. Outfitter clients owned the least number of snowmobiles, averaging 0.6 snowmobiles per household. Seventy percent of outfitter clients did not own any snowmobiles This is expected since not owning a snowmobile is a probably a primary reason for using the services of a snowmobile outfitter. Nonresidents averaged 2.4 snowmobiles.

Table 2. Number of Snowmobiles Currently Owned

	Total Snowmobiles Owned
Outfitter Clients	0.6
Resident	2.6
Nonresident	2.4

Table 3 illustrates when trail users snowmobiled in Wyoming. Each group varied in choosing their snowmobile days. Outfitter clients snowmobiled mainly during normal weekdays, with 61.9 percent of this group snowmobiling during this time, while 54.4 percent of residents snowmobiled during normal weekend days, and 50.0 percent of nonresidents snowmobiling during normal weekdays.

Table 3. Snowmobiling Days

	Weekend Days	Weekdays	Holidays
Outfitter Clients	33.3%	61.9%	4.8%
Resident	54.4%	30.8%	14.8%
Nonresident	42.0%	50.0%	8.0%

Table 4 indicates that each user group traveled varying distances to snowmobile during the season. This is to be expected given the origin of each type of respondent. Not surprisingly, outfitter clients seemed to have traveled the farthest, with 61.3 percent having traveled over 1,000 miles to snowmobile during the season. Nonresidents also traveled relatively far, with 22 percent of them traveling over 1,000 miles to snowmobile during the season. On the other hand, nearly two-thirds of residents traveled less than 200 miles to snowmobile during the season.

Table 4. Maximum Distance Traveled to Snowmobile (one-way miles)

	< 100	100-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	>1000
Outfitter Clients	9.7%	2.9%	2.9%	1.8%	3.2%	2.9%	0.4%	2.5%	5.4%	6.9%	61.3%
Resident	37.2%	29.2%	14.1%	10.1%	3.4%	2.2%	1.0%	1.0%	0.0%	0.2%	1.6%
Nonresident	3.8%	13.1%	9.1%	6.1%	6.6%	9.1%	5.1%	9.0%	7.7%	8.4%	22.0%

Table 5 indicates that the vast majority of resident and nonresident snowmobilers were either satisfied or very satisfied with Wyoming snowmobile opportunities. Only 4.4 percent of resident snowmobilers and 3.3 percent of nonresidents said they were either dissatisfied or very dissatisfied with their Wyoming snowmobile experience. Outfitter clients were asked a similar question, however it was worded differently and thus was not included in this comparison table.

Table 5. Overall Satisfaction with Wyoming Snowmobiling

	Very Satisfied	Satisfied	Dissatisfied	Very Dissatisfied
Resident	52.0%	43.6%	2.4%	2.0%
Nonresident	66.2%	30.5%	1.7%	1.6%

Table 6 indicates that Wyoming snowmobile trail users are fairly split on the issue of cleaner, quieter snowmobiles. More resident and nonresident users felt that there ***was not*** a need for a cleaner, quieter snowmobile, with 50 percent and 61.9 percent stating this. In contrast, over 50 percent (56 percent) of outfitter clients felt that there ***was*** a need for this type of snowmobile.

Table 6. Need for a Cleaner, Quieter Snowmobile

	Yes	No	Don't Know
Outfitter Client	56.0%	26.3%	17.7%
Resident	39.4%	50.0%	10.6%
Nonresident	28.2%	61.9%	9.9%

Table 7 shows that most of the Wyoming snowmobile trail users are willing to pay more to use cleaner, quieter snowmobiles. Over half of residents and nonresidents

(50.2 percent and 50.5 percent, respectively) said they would be willing to pay more to use these machines. However, more outfitter clients (64.4 percent) said they would be willing to pay a higher price to use cleaner, quieter snowmobiles.

Table 7. Willingness to Pay More to Use a Cleaner, Quieter Snowmobile if Readily Available

	Yes	No
Outfitter Client	64.4%	35.6%
Resident	50.2%	49.8%
Nonresident	50.5%	49.5%

Seasonal Trip Information

Table 8 shows that residents were the heaviest users of the snowmobile trails in Wyoming last season, averaging 14.5 trips and 19.0 days per respondent. Nonresidents were next averaging 4.3 trips and 10.8 days, followed by outfitter clients averaging 1.9 trips and 3.9 days. Residents and nonresidents both said that they used the Snowy Range trail system the most, while outfitter clients used Yellowstone National Park the most.

Table 8. Number of Snowmobile Trips and Days During 2000-2001 Season

	WY Trips	WY Days	Highest Use Area
Outfitter Client	1.9	3.9	YNP
Resident	14.5	19.0	Snowy Range
Nonresident	4.3	10.8	Snowy Range

Table 9 indicates that most Wyoming snowmobile trail users had made a snowmobile trip to Yellowstone National Park at some point in their lives. Outfitter clients reported the highest visitation, with 79.3 percent saying they had visited Yellowstone. Only about 20 percent of outfitter clients had not made a snowmobile trip to Yellowstone.

Table 9. Had Taken Snowmobile Trips to Yellowstone National Park

	Yes	No
Outfitter Client	79.3%	20.7%
Resident	58.9%	41.1%
Nonresident	54.2%	45.8%

Table 10 suggests that outfitter clients would make the most changes of all the Wyoming snowmobile trail user groups should the Yellowstone National Park snowmobile ban take effect, with 56.7 percent saying they would change their number of trips to Wyoming. Nonresidents and residents would also be affected, although the number of snowmobilers saying they would change their trips was lower amongst these categories, with 24.5 percent of residents and 34.7 percent of nonresidents saying they would change the number of their snowmobiling trips if a ban were to take effect.

Table 10. Would Change Number of Winter Trips to Wyoming if No Longer Able to Snowmobile in GTNP or YNP

	Yes	No
Outfitter Client	56.7%	43.3%
Resident	24.5%	75.5%
Nonresident	34.7%	65.3%

Table 11 indicates ***how*** trips would change for those that responded with "Yes" in Table 10. Most of the snowmobilers said they would decrease their snowmobile trips if snowmobiling were no longer allowed in the national parks (95.4% for outfitter clients, 92.1% for nonresidents, and 81.1% for residents). Overall, outfitter clients indicated that they would decrease their snowmobile trips to Wyoming by 52.3 percent and their snowmobiling days in Wyoming by 45.5 percent. Overall, residents indicated that they would decrease their snowmobiling trips in Wyoming by 5.0 percent and their snowmobiling days in Wyoming by 8.6 percent. Overall, nonresidents indicated that they would decrease their snowmobiling trips in Wyoming by 10.4 percent and their snowmobiling days in Wyoming by 13.3 percent.

Table 11. Change in Trips if Snowmobiling Not Allowed in GTNP or YNP

	Increase	Decrease	WY Trips	WY Days
Outfitter Client	4.6%	95.4%	-52.3%	-45.5%
Resident	18.9%	81.1%	-5.0%	-8.6%
Nonresident	7.9%	92.1%	-10.4%	-13.3%

Table 12 suggests a strong response with the vast majority of Wyoming snowmobile trail users saying they would not consider going to Yellowstone National Park if their only mechanized access were by snow coach tours. Nearly 85 percent of outfitter clients, over 90 percent of residents, and over 90 percent of nonresidents said they would not consider using snow coachės to access Yellowstone in the winter.

Table 12. Would Consider Going to YNP if Only Mechanized Winter Access was by Snow Coach Tours

	Yes	No
Outfitter Client	15.4%	84.6%
Resident	8.8%	91.2%
Nonresident	6.8%	93.2%

Specific Information on Most Recent Trip

Table 13 indicates that the most heavily used trail areas by Wyoming snowmobile trail users were the Snowy Range, Yellowstone National Park, Togwotee, and the Northern Bighorns during the last snowmobile season. Residents and nonresidents seemed to have similar usage patterns focusing on the Snowy Range and the Northern Bighorns, while outfitter clients focused their usage in the northwestern portion of Wyoming, particularly Yellowstone and Togwotee.

Table 13. Most Recent Trip Snowmobile Area

	First Use Area	Second Use Area
Outfitter Client	YNP	Togwotee
Resident	Snowy Range	North Bighorns
Nonresident	Snowy Range	North Bighorns

Table 14 indicates that the user group with the largest traveling party size was the outfitter clients, with 9.3 people per party. Also, they had the least amount of passenger vehicles, with only 1.2 vehicles. Residents had the smallest traveling party size, with 5.0 people per group and 2.0 passenger vehicles to transport them. Nonresidents averaged 8.5 people per traveling party and 2.8 passenger vehicles. All user groups had about one sled per person, aside from the outfitter clients who indicated that they had more double riders, with 8.3 sleds for the 9.3 people in the traveling party. In some cases outfitter clients may have been reporting the number of people that went on the tour rather than the number in their traveling party.

Table 14. Traveling Party Characteristics

	People in Party	Passenger Vehicles	Snowmobiles
Outfitter Client	9.3	1.2	8.3
Resident	5.0	2.0	4.7
Nonresident	8.5	2.8	8.5

Table 15 suggests that outfitter clients traveled the farthest for their last snowmobiling trip by traveling 1,106 miles. However, it is interesting to note that although outfitter clients reported traveling the farthest distance, nonresidents reported the longest traveling time for their mileage, with 10.6 hours and 631 miles, versus the outfitter client traveling time of 9.0 hours. This is likely due to outfitter clients traveling by airplane, whereas nonresidents were more likely to travel with their snowmachines and thus forced to drive to their Wyoming snowmobile destination.

Table 15. Travel Time and Distance

	Travel Time	Travel Distance
Outfitter Client	9.0 hours	1,106 miles
Resident	2.6 hours	98 miles
Nonresident	10.6 hours	631 miles

Table 16 shows that snowmobiling was the primary purpose of the most recent trip for the majority of all Wyoming snowmobile trail user groups. Over 78 percent of outfitter clients, 89.0 percent of residents, and 97 percent of nonresidents indicated that snowmobiling was their primary purpose for traveling to Wyoming during their most recent trip.

Table 16. Was Snowmobiling Primary Purpose?

	Yes	No
Outfitter Client	78.5%	21.5%
Resident	89.0%	11.0%
Nonresident	97.3%	2.7%

Table 17 indicates how long each user group stayed in Wyoming and how many days they snowmobiled in the state. Outfitter clients generally had the longest stays in Wyoming, with 5.5 nights and 6.1 days in the state. This user group spent 3.5 days snowmobiling. Nonresidents stayed around 4.0 nights and 4.5 days in Wyoming, while snowmobiling 4.1 days. Residents obviously reported the shortest trips during their last snowmobiling trips because they most likely are located close enough to a Wyoming snowmobile trail area to merit only a one or two-day trip (1.2 nights and 2.1 days).

Table 17. Most Recent Snowmobile Trip Length

	Total Nights	Total WY Nights	Total WY Days	Total Snowmobiling Days
Outfitter Client	6.5	5.5	6.1	3.5
Resident	1.1	1.2	2.1	2.0
Nonresident	4.9	4.0	4.5	4.1

Table 18 shows the average usage that snowmobilers placed on the Wyoming trail system during their last snowmobile trip to the state. Nonresident snowmobilers reported the most hours out on the trail system, with 7.5 hours per day and traveling 83.8 miles. Nonresidents also reported purchasing the most gasoline for their machines, with 13.0 gallons per day. However, outfitter clients reported the most mileage traveled, with 92.0 miles per day and only 6.8 hours per day on the snowmobile and purchasing 11.6 gallons per day. Resident usage was not substantially different from the other two user groups, with 5.8 hours per day snowmobiling, traveling 69.7 miles, and purchasing 11.2 gallons of gas for their snowmobiles.

Table 18. Daily Snowmobile Hours, Miles, and Gas Purchases

	Daily Snowmobile Hours	Daily Snowmobile Miles	Daily Snowmobile Gas
Outfitter Client	6.8	92.0	11.6 gallons
Resident	5.8	69.7	11.2 gallons
Nonresident	7.5	83.8	13.0 gallons

Yellowstone National Park Snowmobile Ban Opinion Questions

Table 19 illustrates that a vast majority of Wyoming snowmobilers are aware of the issues surrounding the Yellowstone National Park snowmobile ban. Most outfitter clients (86.5 percent), residents (95.9 percent), and nonresidents (91.4 percent), reported being aware of these issues.

Table 19. Aware of Issues Surrounding YNP Snowmobile Ban?

	Yes	No
Outfitter Client	86.5%	13.5%
Resident	95.9%	4.1%
Nonresident	91.4%	8.6%

Table 20 shows that the majority of all Wyoming snowmobile trail users felt that the decision to ban snowmobiles in Yellowstone National Park was ***not fair***. A few had no opinion on the issue (6.8 percent of outfitter clients, 5.9 percent of residents, and 6.8 percent of nonresidents).

Table 20. Was the NPS Decision to Ban Snowmobiles Fair?

	Yes	No	No Opinion
Outfitter Client	9.7%	83.5%	6.8%
Resident	4.7%	89.4%	5.9%
Nonresident	4.4%	88.8%	6.8%

Table 21 indicates that most Wyoming snowmobilers extended their concern to the future of the snowmobile trails systems outside of Yellowstone. The majority of nonresidents (87.6 percent), residents (86.0 percent), and outfitter clients (61.6 percent) stated that they are concerned about the future of the Wyoming snowmobile trails system outside of Yellowstone National Park.

Table 21. Concerned About Future of Trail Systems Outside of YNP?

	Yes	No
Outfitter Client	61.6%	38.4%
Resident	86.0%	14.0%
Nonresident	87.6%	12.4%

Table 22 indicates the preferred solution of Wyoming snowmobile trail users for snowmobile conflicts in national parks. The most popular alternative for outfitter clients and residents was to have no ban in effect, but to instead have a requirement for cleaner, quieter snowmobiles. Nonresidents preferred no ban and no additional requirements in place.

Table 22. Preferred Solution for Snowmobile Conflict in National Parks

	Most Preferred Solution
Outfitter Client	Cleaner, Quieter Machine Requirement
Resident	Cleaner, Quieter Machine Requirement
Nonresident	No Ban or Other Requirements

Table 23 indicates why user groups come to Wyoming to snowmobile. Outfitter clients said they primarily base their trail choices on the scenery available and the reputation of the snowmobiling experience that a particular Wyoming area has. Residents and nonresidents said they primarily choose their trail areas based on snow conditions and the amount of off-trail powder available.

Table 23. Most Preferred Snowmobile Trail Characteristics

	Main Factor	Second Main Factor
Outfitter Client	Scenery	Reputation
Resident	Snow Conditions	Off-Trail Powder
Nonresident	Snow Conditions	Off-Trail Powder

Wyoming Snowmobiler Characteristics

Table 24 indicates that most frequent origins of the outfitter clients were Michigan and Pennsylvania. The most frequent origin of nonresidents was Minnesota. The most frequent origin of Wyoming residents who snowmobile in the state was Natrona County.

Table 24. Origin of Wyoming Snowmobile Trail Users

	Most Origin	Second Most Origin
Outfitter Client	MI and PA	WY
Resident	Natrona County	Fremont County
Nonresident	MN	CO

Table 25 gives some basic information about Wyoming snowmobile trail users, and there are many similarities between the groups. Most users (regardless of whether they are outfitter clients, residents, or nonresidents) are males between the ages of 36 and 50 years old and work full-time. The main characteristics that separate user groups were the levels of education level (outfitter clients most frequently had obtained college degrees, residents most frequently had some college, while nonresidents most frequently had finished high) and the levels of income (outfitter clients had a large percentage who earned over $100,000 whereas residents and nonresidents both most frequently earned incomes in the $50,000 to $74,999 range).

Table 25. Wyoming Snowmobiler Characteristics

	Gender	Age	Education	Employment	Work Outside Home	Income
Outfitter Client	Male (70.3%)	36-50 years	College Degree	Full-Time	1.4	> $100,000
Resident	Male (91.6%)	36-50 years	Some College	Full-Time	1.6	$50,000-$74,999
Nonresident	Male (92.4%)	36-50 years	High School	Full-Time	1.6	$50,000-$74,999

Economic Impact of Snowmobiling in Wyoming.

Table 26 summarizes the economic impact of snowmobiling in Wyoming. Daily per person trip expenditures in Wyoming ranged from $180.27 for outfitter clients to $98.99 for nonresidents and $68.50 for residents. Annual equipment expenditures in Wyoming ranged from $2,306.13 for residents to $329.94 for nonresidents, and $64.11 for outfitter clients.

In terms of total spending associated with snowmobiling, nonresidents, residents, and outfitter client were estimated to have spent a total of $234.3 million in Wyoming during the 2000-2001 season. Of this amount about 40 percent was from nonresidents, 40 percent was from residents, and nearly 20 percent was from outfitter clients. Based on survey results regarding the reduction in snowmobiling days in Wyoming it is estimate that the banning of snowmobiles in Yellowstone and Grand Teton National Parks could decrease snowmobile expenditures in Wyoming by up to $36.8 million dollars. Over one-half of this loss would be from reduced outfitter client expenditures, which are concentrated in northwest Wyoming. Decreases in nonresident expenditures represent about 35 percent of the loss and decreases in resident expenditures represent slightly more than 12 percent of the loss. To some extent, the loss of resident snowmobile expenditures may actually represent a shifting of this spending to other activities in the state.

Because nonresident and nonresident outfitter client spending represents new money to the Wyoming economy, it is appropriate to consider the economic impact of this spending on the state's economy. An IMPLAN model of the Wyoming economy was used to estimate the economic impact of the $138.4 million of nonresident and nonresident outfitter client spending. It is estimated that this spending directly or secondarily supported over 3,800 jobs and generated over 50.2 million in labor income in the state. Based on survey results regarding the reduction in snowmobiling days in Wyoming it is estimate that the banning of snowmobiles in Yellowstone and Grand Teton National Parks could result in a loss of up to 938 jobs and $11.8 million in labor income in the state.

Finally, snowmobiling is also a source of revenue for state and local governments in Wyoming. During the 2000-2001 season it is estimated that snowmobiling generated over $10.0 million in government revenue. About 70 percent of this revenue is from sale tax, with about one-quarter from gas tax revenue, and five percent from user fees. It is estimated that the banning of snowmobiles in Yellowstone and Grand Teton National Parks would decrease this government revenue by up to $1.3 million.

Table 26. Summary of Economic Impact of Snowmobiling in Wyoming

Expenditures	Daily/Person Trip (WY)	Annual Equip (WY)	
Nonresident Expenditures	$98.99	$329.94	
Resident Expenditures	$68.50	$2,306.13	
Outfitter Client Expenditures	$180.27	$64.11	
	Current Situation	With SMB Ban	Loss From Ban
Nonresident Expenditures	$97,594,577	$84,614,498	$12,980,079
Resident Expenditures	$94,356,462	$89,850,766	$4,505,696
Outfitter Client Expenditures	$42,357,571	$23,084,876	$19,272,695
Total Expenditures	$234,308,610	$197,550,140	$36,758,470
Economic Impact			
Number of Jobs	3,817	2,879	938
Labor Income	$50,246,068	$38,446,073	$11,799,995
State and Local Government Revenue			
Sales Tax Revenue	$7,036,153	$6,140,755	$895,398
Gas Tax Revenue	$2,463,123	$2,126,885	$336,238
Registration/Licensing Fees	$540,088	$483,833	$56,255
Total Government Revenue	$10,039,364	$8,751,474	$1,287,890

SUMMARY AND CONCLUSIONS

Outfitter clients, residents, and nonresidents all have an important impact on Wyoming snowmobiling. Each user group has its own unique characteristics, yet there are many areas where the groups are similar. This report provided some basic comparison points between each user group so that the entire Wyoming snowmobiling picture could be painted. This report will hopefully be a springboard for further analysis to be used for future Wyoming State Trails Program decision-making. The report also indicates the economic importance of snowmobiling in Wyoming and the potential negative economic effects of banning snowmobiling in Yellowstone and Grand Teton National Parks.

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DETERMINATION OF SNOWCOACH EMISSIONS FACTOR

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FINAL REPORT

Prepared for

STATE OF WYOMING
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DEPARTMENT OF EMISSIONS RESEARCH
AUTOMOTIVE PRODUCTS AND EMISSIONS RESEARCH DIVISION

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I. INTRODUCTION

As emissions standards grow more stringent and play a vital role in the operation of vehicles, information needs to be present for different classes of vehicles. While no regulations currently exist for over-snow vehicles, determination of which type of vehicle to operate is largely influenced by the emissions output of these vehicles. Snowcoaches are an "option" being considered in an environmental impact statement (EIS), as a winter transportation replacement for snowmobiles in Yellowstone National Park (YNP). Since they are being considered, accurate emissions factors are needed to compare the relative impacts of these two types of vehicles.

Currently, snowcoaches make up about 10 percent of the winter transportation sector, whereas 90 percent of transportation is by means of snowmobile. In consideration of increasing snowcoach usage, officials are concerned about the environmental impact of operating snowcoaches throughout the park and surrounding areas. The focus of this program is to test a representative vehicle and determine an estimated emissions range over the course of a snowcoach trip. This study will help to understand the typical operation of snowcoaches, identify a general range of emissions generated from snowcoaches, understand how changes in snowcoach operation change emissions, and determine what may be done to more accurately test snowcoaches. To accurately determine an emissions factor would require in-field emissions testing during actual snowcoach operation. While this is conceivable, it would require more time and budget than currently available. As a way of determining an estimated emissions range, we proposed testing a similar wheeled vehicle, in a laboratory, on a chassis dynamometer. Thus, data produced must be viewed as a first approximation of a snowcoach emissions factor.

II. DESCRIPTION OF PROGRAM

A. Test Vehicle

Snowcoaches are enclosed, tracked vehicles that carry passengers over snow through terrain unmanageable by wheeled vehicles. These vehicles currently operate in Yellowstone National Park on tours up to 90 miles in distance. Tours from West Yellowstone, MT travel to two different destinations, Old Faithful and the Canyon. Distances traveled for a given trip are 60 and 90 miles, respectively. Various types of snowcoaches are in operation ranging from dedicated production snowcoaches, to 4-wheel drive trucks fitted with a track at each wheel, to conversion vans with tracks in the rear and skis in the front. An inventory of snowcoaches operated commercially in and around Yellowstone National Park is listed in Table 1.(1) The majority of these vehicles are converted passenger vans, that ride on tracks at the drive wheels and skis at the front wheels. These vehicles are limited to low speed operation, 25-30 mph, to preserve the integrity of the mechanical components, mainly the transmission and cleated tracks. A van representative of the conversion was emission tested on a chassis dynamometer at Southwest Research Institute (SwRI) in San Antonio, Texas.

TABLE 1. COMMERCIAL INVENTORY OF SNOWCOACHES IN OPERATION AROUND YNP

Production Year	Model	Engine/Fuel	Approximate Number in Operation	Max. No. of Passengers per Coach
1956-1963	Bombardier	Gasoline V8	54	10
1999	Ford E-350 Clubwagon XLT	Triton V10 Gasoline/EFI	4	15
1989	Chevy C2500 Van	Gasoline V8	N/A	15
Varies by vehicle	MPCMac Trax Tread Conversions (Chevy 1500 Suburban, 1500 Silverado)	Gasoline V8	N/A	Varies by vehicle
Photos of various snowcoaches are shown in Appendix A				

The vehicle chosen for study in this project is a converted 1999 Ford E-350 15 passenger van with a Triton V-10 EFI gasoline engine. This vehicle is shown in Figure 1. During the conversion, the vehicle is fitted with a track system, and the rear axle is changed to increase engine speed during operation, thus operating within the maximum power band of the engine. In addition, the stock transmission is replaced after the first year of use due to substantial wear and tear created by snowcoach operation.

FIGURE 1. CONVERSION FORD E-350 SNOWCOACH

Since testing was to be done in an emissions laboratory, an equivalent wheeled vehicle was selected for testing on a chassis dynamometer using conditions designed to approximate snowcoach operation. The vehicle tested in this project was a 2000 Ford E-350 Clubwagon XLT, equipped with a Triton EFI V-10 engine.

Due to time and budget constraints, much of the information used to generate a representative drive cycle and road load schedule was based on professional experience from snowcoach operation and emissions testing. The only data available to assist in the development of the drive cycle and road load curves was based on fuel logs obtained from snowcoach owners. Information from these logs may be reviewed in Appendix B.

B. Drive Cycle Determination

When testing automobile emissions, vehicles are driven over a predetermined cycle to establish baseline emissions, which can then be compared between different vehicles within the same classification. Drive cycles need to be representative of in-field operation to most accurately reflect in-use emissions. Since a snowcoach is not a typical vehicle, predefined cycles (FTP, ECE, US06) would not reflect real-world emissions. Due to this reason, a new driving cycle was developed to represent typical snowcoach operation in the YNP area.

In development of the snowcoach driving cycle, information was gathered from snowcoach owners and operators to define vehicle operating parameters. It should be noted that this cycle was developed solely from the experience of operators, due to the lack of snowcoach data. Parameters used to help define the cycle were trip time, peak and average speeds, distance, acceleration capabilities and limits, decelerations, driving versus park/idle time, and low speed operation time. Operator information used to generate the driving cycle, along with other drive cycle information, is in Appendix C. Using the above information, a driving cycle was produced with performance characteristics shown in Table 2.

TABLE 2. SNOWCOACH DRIVE CYCLE PARAMETERS

Steepest acceleration	0-26 mph in 113 sec 0-9 mph in 46 sec
Steepest Decel	8-0 mph in 10 sec
Time at Speeds (117 sec)	at 5 mph=25 sec at 8 mph= 22 sec at 9 mph=30 sec at 10 mph=30 sec
Total Cycle Time	1200 sec
Idle Time	115 sec
Average Vehicle Speed	13.7 mph
Distance Traveled during cycle	4.56 miles
Time to travel 60 miles	4.39 hrs
Time to travel 90 miles	6.59 hrs

A representative drive cycle was developed based on snowcoach operator input. Figure 2 shows two drive cycles, the shaded, blue curve representing the snowcoach as operated in the field, and the solid, red curve representing the cycle driven during testing of the stock vehicle on the chassis dynamometer at SwRI.

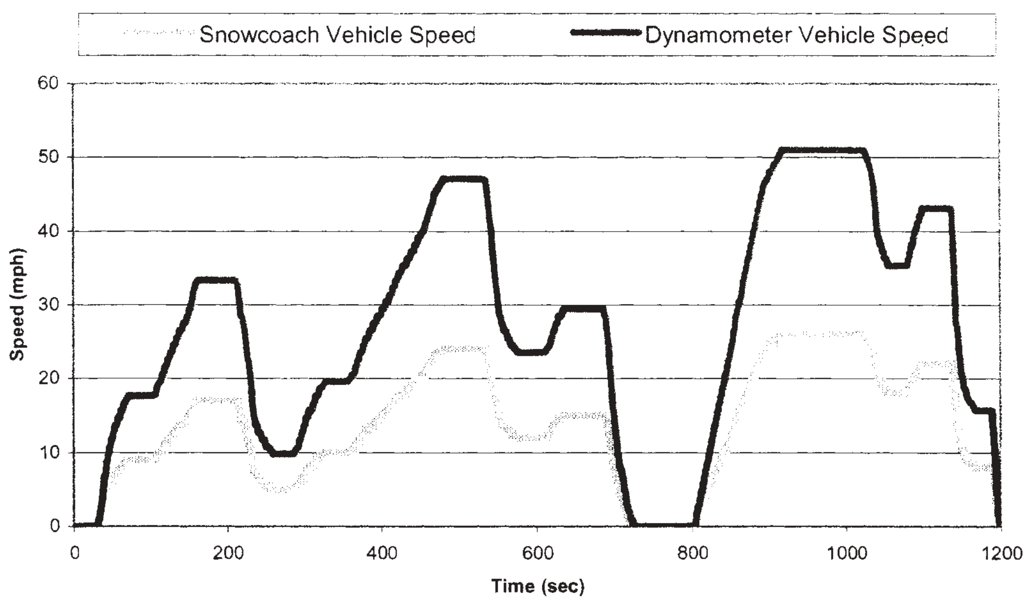


FIGURE 2. SNOWCOACH AND DYNAMOMETER DRIVE CYCLES

The dynamometer speed trace required "translation" to account for changes to the stock vehicle final drive ratio during the conversion process. To accomplish this, a scalar was applied to the snowcoach curve to generate the dynamometer drive trace. The scalar factor of 1.96 that was applied to the drive cycle referenced a snowcoach speedometer reading of 55 mph alongside a snowmobile traveling at 28 mph. Using this adjusted curve allows for testing the vehicle with the engine operating at approximately the same speeds as in the field.

C. Road Load Curve Derivation

In addition to the development of a driving cycle, an equivalent road load curve was needed to simulate the in-field power demands. Again, due to the lack of actual data, power requirements were derived mainly by trial and error.

The main criteria for determining the vehicle loading referenced fuel consumption logs.(2) Information from the fuel logs is summarized in Table 3. The average fuel economy numbers were the target for determining are representative road load for this vehicle. Knowing the consumption of fuel that occurs over a given trip, and thus the fuel economy of the vehicle, allows for an approximation of road load. This requires running the vehicle on a chassis dynamometer, assigning a set of dynamometer load coefficients, driving the vehicle over the dynamometer driving cycle and adjusting the road load to match the targeted fuel consumption based on the fuel logs. Once a reference is generated, the load may be adjusted to produce the targeted fuel economy.

TABLE 3. AVERAGE FUEL ECONOMY AND PASSENGER LOADS OF SNOWCOACHES (BASED ON FUEL LOGS)

Destination	Average No. of Passengers	Miles Traveled	Fuel Consumption, gal	Fuel Economy, mpg
Canyon	6	90	28	3.22
Old Faithful	7	60	20	3.04

In order to generate a starting load, calculations from Bombardier Corp. were applied to find an approximate force required to propel a tracked vehicle of this nature.(3) Bombardier produces a variety of tracked vehicles for different commercial and recreational applications. It was suggested that a vehicle such as this would require a force equivalent to 10 percent of the vehicle's mass to maintain motion across all speeds. In the case of a snowcoach, the test weight was equal to 9150 lb as shown in the following equation:

$$W = \textit{Curb Weight} + \textit{Track Weight} + \textit{Passenger Weight}$$

$$W = 6515\,lb + 1000\,lb + 150\,lb \times 10\ \textit{passengers} = 9015\,lb$$

$$W_T = \textit{Test Weight} = 1.015^{*} \times 9015\,lb = 9150\,lb$$

*The 1.015 scalar is an adjustment for setting the simulated dynamometer inertia

This results in a target loading of approximately 915 lb of force at the drive wheels to operate in the over-snow environment. Since this value exceeds the capacity of our light-duty 48-inch roll chassis dynamometer, vehicle loading was limited to a maximum of 875 lb to prevent damaging equipment.

D. Test Program

Testing utilized a Horiba 48-inch single-roll chassis dynamometer. This dynamometer electrically simulates inertia weights up to 12,000 lb over the specified driving cycles, and provides programmable road load simulation of up to 125 hp continuous at 65 mph. The "a", "b", and "c" coefficients used for baseline testing of the stock vehicle were determined for this vehicle in a previous SwRI project.(4)

Several tests were run on the stock Ford van. All tests were run with commercial-grade 87 octane unleaded gasoline, using an inertia setting of 9150 lb, and driven over the dynamometer driving cycle. Prior to each test, the vehicle was driven over a five minute warmup cycle to precondition the powertrain. Cycle emissions were drawn from a constant-volume sampling system (CVS), accumulated in bags, and analyzed at the conclusion of each testing cycle. Several tests were performed on the stock vehicle at various loads and engine intake air restrictions. Emissions test conditions are summarized in Table 4.

TABLE 4. SNOWCOACH TESTING MATRIX

Test No.	Road Load Setting (Dynamometer Coefficients)			Intake Air Restriction (MAP "Hg)
Baseline-1	A=16.63 lb	B=.0678 $^{lb}/_{mph}$	C=.041 $^{lb}/_{mph}{}^2$	none (29.27)
Baseline-2	A=16.63 lb	B=.0678 $^{lb}/_{mph}$	C=.041 $^{lb}/_{mph}{}^2$	none (29.27)
600-1	A=600 lb	B=0 $^{lb}/_{mph}$	C=0 $^{lb}/_{mph}{}^2$	none (29.31)
875-1	A=875 lb	B=0 $^{lb}/_{mph}$	C=0 $^{lb}/_{mph}{}^2$	none (29.38)
875-2	A=875 lb	B=0 $^{lb}/_{mph}$	C=0 $^{lb}/_{mph}{}^2$	none (29.39)
875-3	A=875 lb	B=0 $^{lb}/_{mph}$	C=0 $^{lb}/_{mph}{}^2$	90% restricted (~23.64 at WOT)

The "road load setting," shown in Table 4, is based on the drive wheel force calculated from the following equation:

$$F_d\,(lb) = A + B \times V + C \times V^2 \qquad \textit{where } V = \textit{vehicle speed in mph}$$

Testing began with two baseline emissions tests. These baseline tests represented the stock van road load coefficients and inertia settings for a snowcoach following the dynamometer driving cycle. These baseline tests allow for comparison of emissions between the stock vehicle and a more heavily loaded vehicle to determine how tailpipe emissions are affected by load. In addition, an intermediate load setting of 600 lb was used to examine whether or not emissions followed some type of trend. Conditions that seemed to most closely represent field operation were achieved by operating the vehicle under 875 lb of load, the maximum capacity of the dynamometer. The above mentioned tests were performed with the vehicle operating in closed loop control, thus allowing the engine to control the air-fuel ratio to theoretically achieve complete combustion. This normally leads to reduced emissions and improved fuel economy. Finally, to show how this vehicle operates in open loop control, the vehicle was tested with the 875 lb load, as well as a partial intake air restriction to simulate the altitude of Yellowstone National Park. For this test, the restriction was set such that it simulated the altitude at one operating point (100% throttle, 1000 RPM) and presented only a partial restriction at all other operating points. The culmination of these tests estimates the emissions from the vehicle while operating in either closed loop or open loop control.

Closed loop operation refers to operating the engine with feedback control, principally to maintain the air/fuel ratio near stoichiometric conditions. On the other hand, when operating in open loop, the control system disregards feedback and operates such that it meets specific mandatory criteria, in this case to meet the speed and power requirements posed on the vehicle. This presents another variable to determining emissions because operation outside of closed loop <u>drastically</u> increases emissions levels. It is not known how often snowcoaches operate in closed loop vs. open loop mode, however, it is suspected that the presence of high loads and high altitude would most likely cause the vehicle to operate in a power enrichment mode (open loop operation).

III. RESULTS AND DISCUSSION

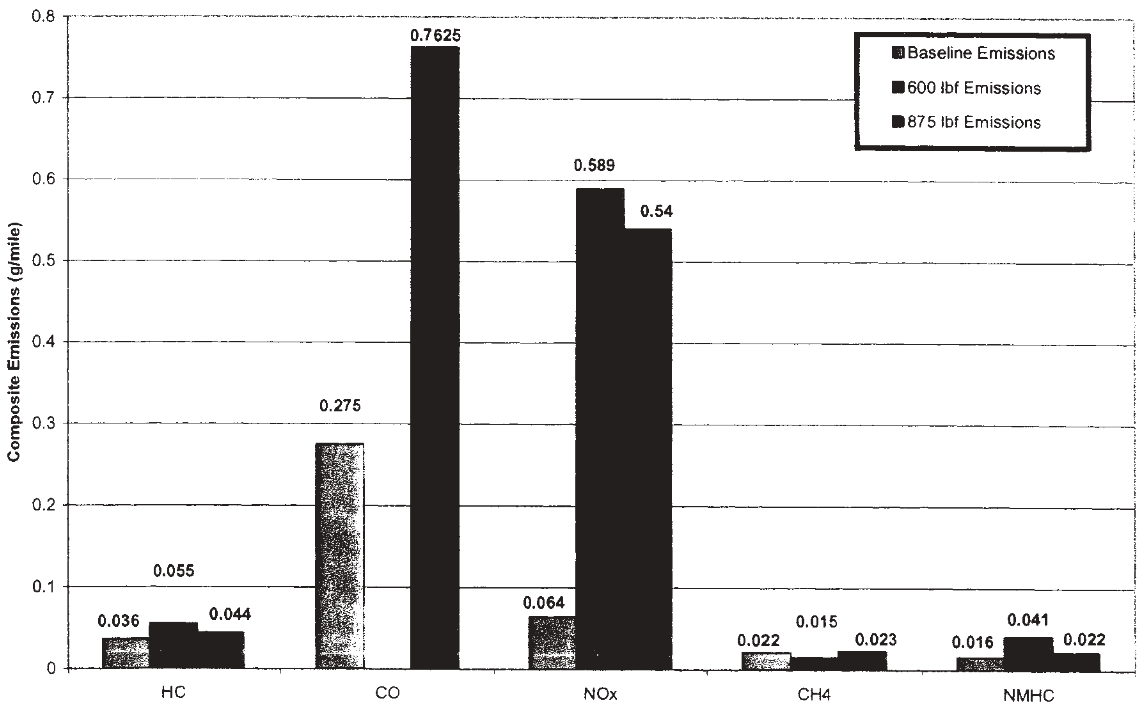
A. Determination of Results

Emissions measured included hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and carbon dioxide (CO_2). HC, CO, and NO_x emissions are regulated by the Environmental Protection Agency (EPA) for light-duty vehicles, utility engines, and heavy-duty engines, however, there are no current regulations for over-snow vehicles. In addition, methane (CH_4) and non-methane hydrocarbon (NMHC) emissions were also measured.

Due to dynamometer limitations, achieving the exact in-field vehicle performance was not possible. Therefore, the threshold for vehicle loading was set at 875 lb. As stated above, emissions levels are reported for closed loop and open loop operation.

B. Snowcoach Emissions

From the results presented in Figure 3, it is noticeable that for closed loop operation, HC emissions vary only slightly when an increase in load is present. Similarly, this is the case for CH_4 and NMHC emissions. On the other hand, CO and NO_x emissions increase more significantly with load, but other than an increase, no trend can be assigned. For the



*no CO emissions data present for 600 lbf test (error in measurement)

FIGURE 3. SNOWCOACH EMISSIONS IN CLOSED LOOP CONTROL*

most part, as long as the vehicle stays in closed loop control, emission levels remain low and controlled. This trend is typical with increases in vehicle loading due to the need of providing specific power and thus controlling the engine to run slightly rich. In most vehicle applications high power demands are not present unless extreme conditions exist, such as trailer towing or climbing a grade, whereas snowcoach operation requires a greater amount of power due to the loads of over-snow operation. One strategy that this particular engine uses to lower NO_x emissions is through the use of exhaust gas recirculation (EGR). EGR for this engine is typically only effective at engine speeds and loadslower than 2800 RPM and 250 ft-lb of torque. Therefore, it is assumed that the EGR system does not reduce the NO_x emissions during increased load operation.

Figure 4 presents one of the largest changes in emissions, that of CO_2. This is expected because CO_2 emissions are directly related to the quantity of fuel burned; and given the targeted fuel economy of 3.1 mpg, CO_2 emissions would be expected to be about four times baseline emissions.

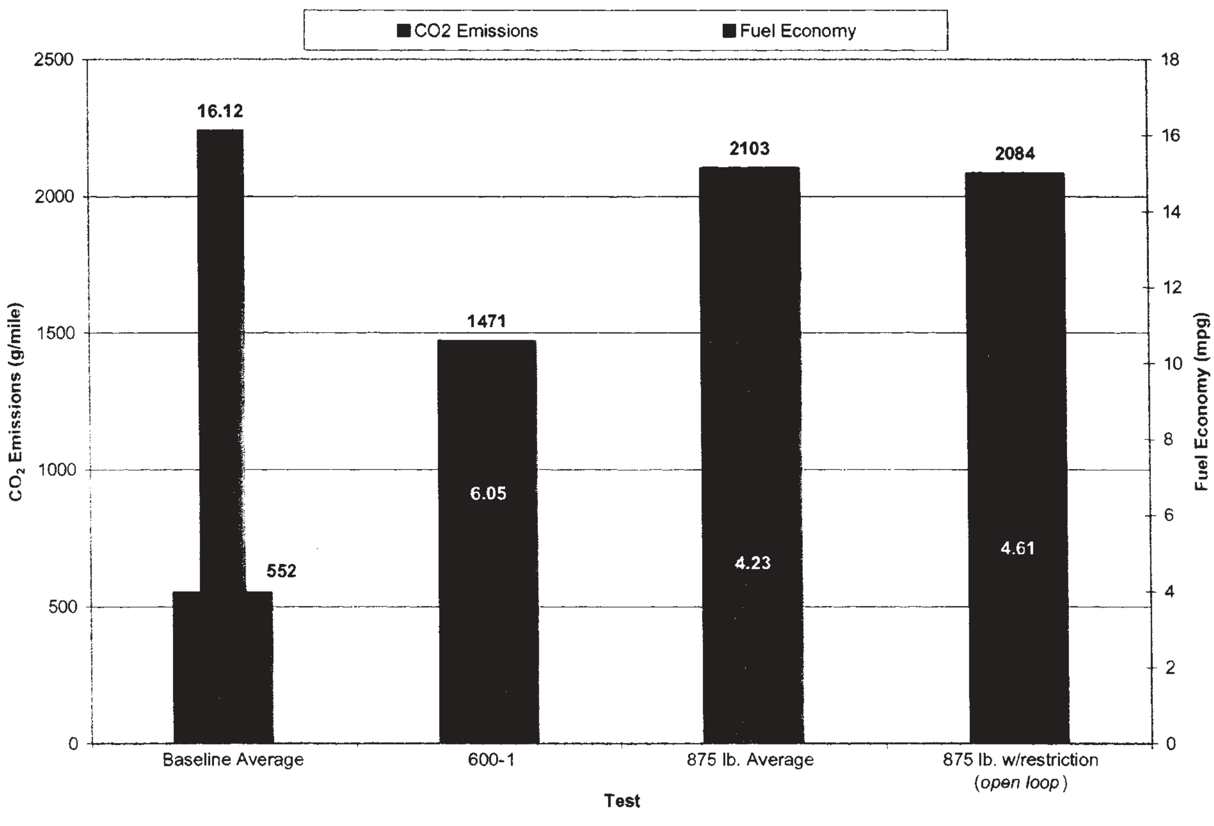


FIGURE 4. FUEL ECONOMY AND CO_2 EMISSIONS OF REPRESENTED SNOWCOACH

As mentioned earlier, open loop control drastically increases engine emissions as fuel and emissions control are sacrificed to provide maximum performance. It was hoped that the large dynamometer loading (875 lb) would send the vehicle into open loop control, however, this did not occur. To achieve open loop operation, a restriction was created in the engine's intake air stream. This restriction was an attempt to simulate the expected manifold air pressure (MAP) at an increased altitude, thereby creating lower inlet air pressures, reducing air intake, and forcing fuel rich operation. This approach caused the vehicle to operate in open loop control and produced the emissions results shown in Figure 5. HC, NO_x and CO emissions increased exponentially in comparison to closed loop emissions. It was also noticed that CO_2 emissions were similar to what was seen in the 875 lb tests during closed loop operation. It can be said that the emissions generated in open loop control would represent a worst case scenario of snowcoach operation for the converted passenger vans.

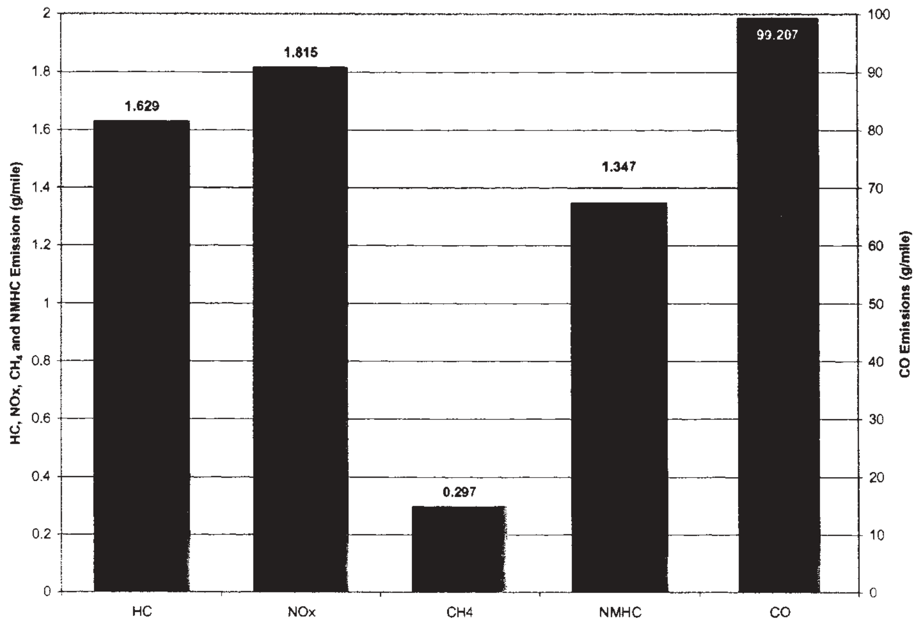


FIGURE 5. OPEN LOOP EMISSIONS

As a comparison, Table 5 shows the range snowcoach emissions would fall within for the converted Ford snowcoach vans. It should be noted that it is expected for CO_2 emissions to be slightly higher in the field due to a greater load present than what was tested.

TABLE 5. EMISSIONS COMPARISON BETWEEN CONTROL OPERATIONS AT 875 LB LOAD

	Closed-Loop Control Emissions	Open-Loop Control Emissions
HC, g/mile	0.044	1.63
CO, g/mile	0.76	99.2
NO_x, g/mile	0.54	1.82
CH_4, g/mile	0.023	0.297
NMHC, g/mile	0.02	1.35
CO_2, g/mile	2103	2084

IV. SUMMARY AND RECOMMENDATIONS

Snowcoaches are unique vehicles with respect to both their environment as well as their operating characteristics. Since real-time operating information about snowcoaches is unknown, it can be best concluded that snowcoaches generate emissions within a specific range and not simply one applicable set of numbers. Through the work of this project, it has been shown that vehicle loads, as well as environmental conditions, affect both fuel consumption and emissions. The following can be concluded:

- Closed loop versus open loop operation greatly affects emissions, and depending on the duration of vehicle operation in open loop control, the emissions output of snowcoaches will rise significantly.

- The emissions range estimated is only representative of the converted Ford vans. It is unknown how this range would apply to other types of snowcoach vehicles.

Although a better understanding regarding snowcoach operation has been gained, much information used to determine operating conditions was based on operator experience rather than field data. In addition, an approximation or simulation of only one type of snowcoach was explored in this study. It is recommended that some additional studies be performed such that accurate emissions results may be known for specific vehicle types. From this experience, it is recommended that:

- Multiple models of snowcoaches be instrumented and operated in-field to measure operating characteristics and real-time emissions. This would allow for a determination of: an appropriate driving cycle, engine control operation information, operation changes due to changes in climate and altitude, and emissions changes due to variation in operating conditions.

V. REFERENCES

1. "Snowcoach Variants," e-mail to Jeff White from Howard Haines, August 6,2001.

2. "Three Bear Lodge" Fuel Log Recap, documentation provided by Clyde Seely, Oct. 22, 2001.

3. Bombardier Corporation, telephone conversation with Mike Pellegtier, Oct. 29, 2001.

4. Whitney, Kevin, "An Investigation of Rover's Capabilities to Accurately Measure the In-Use Activity and Emissions of Late-Model Diesel and Gasoline Trucks," Final Report to EPA under Contract 68-C-98-158, Work Assignment No. 1-03, July 2000.

APPENDIX A

PHOTOGRAPHS OF SNOWCOACHES

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FIGURE A-1. BOMBARDIER SNOWCOACH

FIGURE A-2. MPCMac TRAX TREAD CONVERSION (shown on a utility vehicle)

FIGURE A-3. 1989 CHEVY C2500 AMFAC CONVERSION SNOWCOACH

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APPENDIX B

FUEL LOGS

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TABLE B-1. SNOWCOACH FUEL USAGE LOG

Date	Destination	Snowcoach No.	Total No. of People	Total Miles Traveled	Gallons of Fuel Consumed	Fuel Economy (mpg)
01/01/01	Old Faithful	3	12	60	21.9	2.74
01/02/01	Old Faithful	4	9	60	22	2.73
01/04/01	Old Faithful	3	7	60	18	3.33
01/11/01	Old Faithful	3	8	60	19.5	3.08
01/11/01	Old Faithful	5	9	60	20.8	2.88
01/23/01	Old Faithful	3	7	60	24.5	2.45
01/15/01	Old Faithful	3	6	60	18.9	3.17
01/15/01	Old Faithful	1	11	60	22	2.73
01/16/01	Old Faithful	1	8	60	16.8	3.57
01/16/01	Old Faithful	3	8	60	21.6	2.78
01/17/01	Old Faithful	3	6	60	16.2	3.70
01/20/01	Old Faithful	3	8	60	19	3.16
01/02/01	Canyon	3	3	90	26	3.46
01/12/01	Canyon	4	8	90	30.3	2.97
01/16/01	Canyon	2	6	90	29.2	3.08
01/19/01	Canyon	5	3	90	27	3.33
01/20/01	Old Faithful	1	6	60	18.1	3.31
01/21/01	Old Faithful	3	8	60	19.7	3.05
01/21/01	Old Faithful	1	4	60	16.8	3.57
01/22/01	Old Faithful	3	6	60	18.6	3.23
01/22/01	Old Faithful	2	8	60	20.2	2.97
01/25/01	Old Faithful	2	8	60	18	3.33
01/25/01	Canyon	4	4	90	29.1	3.09
01/27/01	Canyon	4	5	90	28	3.21
01/29/01	Old Faithful	1	8	60	18.4	3.26
01/30/01	Old Faithful	3	8	60	19.7	3.05
01/31/01	Old Faithful	4	8	60	21.5	2.79
02/01/01	Old Faithful	N/A	6	60	24	2.50
02/01/01	Canyon	N/A	3	90	27.9	3.23
02/02/01	Old Faithful	N/A	4	60	18	3.33
02/03/01	Old Faithful	N/A	6	60	22.2	2.70
02/04/01	Old Faithful	N/A	3	60	22.8	2.63
02/06/01	Old Faithful	N/A	4	60	19	3.16
02/07/01	Canyon	N/A	9	90	28.2	3.19
02/10/01	Canyon	N/A	N/A	90	31.6	2.85
02/16/01	Old Faithful	N/A	7	60	21.3	2.82
01/21/01	Canyon	N/A	11	90	24	3.75

TABLE B-2. AVERAGED DATA FROM FUEL LOGS

Average Fuel Economy for Snowcoach Trip based on Destination		Average Number of Passengers per Trip based on Destination		Average Fuel Consumption per Trip based on Destination	
Old Faithful Trip	Canyon Trip	Old Faithful Trip	Canyon Trip	Old Faithful Trip	Canyon Trip
2.74		12		22	
2.73		9		22	
3.33		7		18	
3.08		8		20	
2.88		9		21	
2.45		7		25	
3.17		6		19	
2.73		11		22	
3.57		8		17	
2.78		8		22	
3.70		6		16	
3.16		8		19	
	3.46		3		26
	2.97		8		30
	3.08		6		29
	3.33		3		27
3.31		6		18	
3.05		8		20	
3.57		4		17	
3.23		6		19	
2.97		8		20	
3.33		8		18	
	3.09		4		29
	3.21		5		28
3.26		8		18	
3.05		8		20	
2.79		8		22	
2.50		6		24	
	3.23		3		28
3.33		4		18	
2.70		6		22	
2.63		3		23	
3.16		4		19	
	3.19		9		28
	2.85		N/A		32
2.82		7		21	
	3.75		11		24
3.04	**3.22**	**7**	**6**	20	28

APPENDIX C

DRIVE CYCLE PARAMETERS

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TABLE C-1. ESTIMATED DRIVING PARAMETERS FROM DEVELOPED SNOWCOACH DRIVE CYCLE

	Distance (miles)	Assuming Max. Average Speed Travel		Assuming Average Speed Travel	
		Driving Time (hrs.)	Idle/Off Time (hrs.)	Driving Time (hrs.)	Idle/Off Time (hrs.)
Old Faithful Round Trip	60	2.4	5.6	4.4	3.6
Canyon Round Trip	90	3.6	4.4	6.6	1.4

TABLE C-2. ESTIMATED DRIVING PARAMETERS SPECIFIED FROM SNOWCOACH OPERATORS

Total trip time	8 hrs.
Time spent driving at 5-10 mph	.84 hrs.
Maximum Speed	28 mph
Maximum Average Speed	25 mph
Targeted Average Speed	13.66 mph
Acceleration Rate	0-25 mph in ~100 sec

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APPENDIX D

EMISSIONS TEST DATA

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SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 2.5-R 1-BAG EPA FTP VEHICLE EMISSION RESULTS PROJECT NO. 08-5053-001

VEHICLE NUMBER 585	TEST BASELINE 1	GASOLINE EM-0000-F
VEHICLE MODEL 1 FORD VAN	DATE 11/ 6/2001 RUN	FUEL DENSITY 6.176 LB/GAL
ENGINE 6.8 L (415 CID)-	DYNO 5 BAG CART 4	H .133 C .867 O .000 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 16.36 HP (12.20 KW)	FTP
ODOMETER 20555 MILES (33072 KM)	TEST WEIGHT 9150 LBS (4149 KG)	

BAROMETER 29.27 IN HG (743.5 MM HG) DRY BULB TEMPERATURE 70.0°F (21.1°C) NOX HUMIDITY C.F. .926

RELATIVE HUMIDITY 51.9 PCT.

BAG NUMBER	1
BAG DESCRIPTION	
RUN TIME SECONDS	581.2
DRY/WET CORRECTION FACTOR, SAMP/BACK	.977/.987
MEASURED DISTANCE MILES (KM)	8.94 (14.38)
BLOWER FLOW RATE SCFM (SCMM)	929.2 (26.31)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)
TOTAL FLOW SCF (SCM)	9001. (254.9)
HC SAMPLE METER/RANGE/PPM (BAG)	5.6/ 1/ 5.59
HC BCKGRD METER/RANGE/PPM	4.1/ 1/ 4.12
CO SAMPLE METER/RANGE/PPM	9.4/ 1/ 9.41
CO BCKGRD METER/RANGE/PPM	.6/ 1/ .64
CO2 SAMPLE METER/RANGE/PCT	1.1/ 1/ 1.0910
CO2 BCKGRD METER/RANGE/PCT	.0/ 1/ .0434
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	1.3/ 1/ 1.26
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .22
CH4 SAMPLE PPM (1.101)	2.96
CH4 BCKGRD PPM	2.13
DILUTION FACTOR	12.38
HC CONCENTRATION PPM	1.80
CO CONCENTRATION PPM	8.47
CO2 CONCENTRATION PCT	1.0511
NOX CONCENTRATION PPM	1.06
CH4 CONCENTRATION PPM	1.00
NMHC CONCENTRATION PPM	.70
HC MASS GRAMS	.265
CO MASS GRAMS	2.515
CO2 MASS GRAMS	4905.33
NOX MASS GRAMS	.478
CH4 MASS GRAMS	.170
NMHC MASS GRAMS (FID)	.103
FUEL MASS KG	1.546
FUEL ECONOMY MPG (L/100KM)	16.19 (14.53)

1-BAG COMPOSITE RESULTS

HC	G/MI	.030	CH4	G/MI	.019
CO	G/MI	.281	NMHC	G/MI	.012
NOX	G/MI	.053			

FUEL ECONOMY MPG (L/100KM) 16.19 (14.53)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 2.5-R   1-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-5053-001

VEHICLE NUMBER 585	TEST BASELINE 2	GASOLINE EM-0000-F
VEHICLE MODEL 1 FORD VAN	DATE 11/ 6/2001 RUN	FUEL DENSITY 6.176 LB/GAL
ENGINE 6.8 L (415 CID)-	DYNO 5 BAG CART 4	H .133 C .867 O .000 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 16.36 HP (12.20 KW)	FTP
ODOMETER 20555 MILES (33072 KM)	TEST WEIGHT 9150 LBS (4149 KG)	

BAROMETER 29.27 IN HG (743.5 MM HG)   DRY BULB TEMPERATURE 70.0°F (21.1°C)   NOX HUMIDITY C.F. .926

RELATIVE HUMIDITY 51.9 PCT.

BAG NUMBER	1
BAG DESCRIPTION	
RUN TIME SECONDS	1201.0
DRY/WET CORRECTION FACTOR, SAMP/BACK	.977/.987
MEASURED DISTANCE MILES (KM)	8.95 (14.41)
BLOWER FLOW RATE SCFM (SCMM)	449.7 (12.73)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)
TOTAL FLOW SCF (SCM)	9001. (254.9)
HC SAMPLE METER/RANGE/PPM (BAG)	6.1/ 1/ 6.06
HC BCKGRD METER/RANGE/PPM	3.8/ 1/ 3.80
CO SAMPLE METER/RANGE/PPM	8.4/ 1/ 8.43
CO BCKGRD METER/RANGE/PPM	.0/ 1/ .00
CO2 SAMPLE METER/RANGE/PCT	1.1/ 1/ 1.1025
CO2 BCKGRD METER/RANGE/PCT	.0/ 1/ .0428
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	1.6/ 1/ 1.62
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .14
CH4 SAMPLE PPM (1.101)	3.17
CH4 BCKGRD PPM	2.08
DILUTION FACTOR	12.25
HC CONCENTRATION PPM	2.57
CO CONCENTRATION PPM	8.11
CO2 CONCENTRATION PCT	1.0632
NOX CONCENTRATION PPM	1.48
CH4 CONCENTRATION PPM	1.26
NMHC CONCENTRATION PPM	1.18
HC MASS GRAMS	.376
CO MASS GRAMS	2.407
CO2 MASS GRAMS	4961.75
NOX MASS GRAMS	.670
CH4 MASS GRAMS	.214
NMHC MASS GRAMS (FID)	.173
FUEL MASS KG	1.564
FUEL ECONOMY MPG (L/100KM)	16.04 (14.67)

1-BAG COMPOSITE RESULTS

HC	G/MI	.042	CH4	G/MI	.024
CO	G/MI	.269	NMHC	G/MI	.019
NOX	G/MI	.075			

FUEL ECONOMY MPG (L/100KM) 16.04 (14.67)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 2.5-R   1-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-5053-001

VEHICLE NUMBER 585	TEST 600-1	GASOLINE EM-0000-F
VEHICLE MODEL 1 FORD VAN	DATE 11/ 6/2001 RUN	FUEL DENSITY 6.176 LB/GAL
ENGINE 6.8 L (415 CID)-	DYNO 5 BAG CART 4	H .133 C .867 O .000 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD 80.00 HP (59.68 KW)	FTP
ODOMETER 20555 MILES (33072 KM)	TEST WEIGHT 9150 LBS (4149 KG)	

BAROMETER 29.31 IN HG (744.5 MM HG)   DRY BULB TEMPERATURE 73.0°F (22.8°C)   NOX HUMIDITY C.F. .859

RELATIVE HUMIDITY 32.6 PCT.

BAG NUMBER	1
BAG DESCRIPTION	
RUN TIME SECONDS	1221.9
DRY/WET CORRECTION FACTOR, SAMP/BACK	.972/.991
MEASURED DISTANCE MILES (KM)	8.90 (14.32)
BLOWER FLOW RATE SCFM (SCMM)	599.3 (16.97)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)
TOTAL FLOW SCF (SCM)	12204. (345.6)
HC SAMPLE METER/RANGE/PPM (BAG)	5.5/ 1/ 5.54
HC BCKGRD METER/RANGE/PPM	3.6/ 1/ 3.63
CO SAMPLE METER/RANGE/PPM	.4/ 1/ .44
CO BCKGRD METER/RANGE/PPM	.0/ 1/ .00
CO2 SAMPLE METER/RANGE/PCT	2.1/ 1/ 2.1057
CO2 BCKGRD METER/RANGE/PCT	.0/ 1/ .0439
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	9.3/ 1/ 9.30
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .08
CH4 SAMPLE PPM (1.101)	2.21
CH4 BCKGRD PPM	1.93
DILUTION FACTOR	6.42
HC CONCENTRATION PPM	2.48
CO CONCENTRATION PPM	.42
CO2 CONCENTRATION PCT	2.0686
NOX CONCENTRATION PPM	9.23
CH4 CONCENTRATION PPM	.58
NMHC CONCENTRATION PPM	1.85
HC MASS GRAMS	.494
CO MASS GRAMS	.169
CO2 MASS GRAMS	13090.29
NOX MASS GRAMS	5.244
CH4 MASS GRAMS	.133
NMHC MASS GRAMS (FID)	.368
FUEL MASS KG	4.122
FUEL ECONOMY MPG (L/100KM)	6.05 (38.89)

1-BAG COMPOSITE RESULTS

HC	G/MI	.055	CH4	G/MI	.015
CO	G/MI	.019	NMHC	G/MI	.041
NOX	G/MI	.589			

FUEL ECONOMY MPG (L/100KM) 6.05 (38.89)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 2.5-R   1-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-5053-001

VEHICLE NUMBER 585	TEST 875-1	GASOLINE EM-0000-F
VEHICLE MODEL 1 FORD VAN	DATE 11/ 7/2001 RUN	FUEL DENSITY 6.176 LB/GAL
ENGINE 6.8 L (415 CID)-	DYNO 5 BAG CART 4	H .133 C .867 O .000 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD ***** HP (87.04 KW)	FTP
ODOMETER 20555 MILES (33072 KM)	TEST WEIGHT 9150 LBS (4149 KG)	

BAROMETER 29.38 IN HG (746.3 MM HG)   DRY BULB TEMPERATURE 73.0°F (22.8°C)   NOX HUMIDITY C.F. .923

RELATIVE HUMIDITY 46.4 PCT.

BAG NUMBER	1
BAG DESCRIPTION	
RUN TIME SECONDS	1201.0
DRY/WET CORRECTION FACTOR, SAMP/BACK	.957/.987
MEASURED DISTANCE MILES (KM)	8.95 (14.40)
BLOWER FLOW RATE SCFM (SCMM)	571.4 (16.18)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)
TOTAL FLOW SCF (SCM)	11437. (323.9)
HC SAMPLE METER/RANGE/PPM (BAG)	6.0/ 1/ 6.00
HC BCKGRD METER/RANGE/PPM	4.3/ 1/ 4.32
CO SAMPLE METER/RANGE/PPM	19.6/ 1/ 19.55
CO BCKGRD METER/RANGE/PPM	1.4/ 1/ 1.40
CO2 SAMPLE METER/RANGE/PCT	3.3/ 1/ 3.2646
CO2 BCKGRD METER/RANGE/PCT	.0/ 1/ .0477
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	5.5/ 1/ 5.53
NOX BCKGRD METER/RANGE/PPM	.1/ 1/ .11
CH4 SAMPLE PPM (1.101)	2.99
CH4 BCKGRD PPM	2.52
DILUTION FACTOR	4.14
HC CONCENTRATION PPM	2.72
CO CONCENTRATION PPM	16.99
CO2 CONCENTRATION PCT	3.2284
NOX CONCENTRATION PPM	5.45
CH4 CONCENTRATION PPM	1.07
NMHC CONCENTRATION PPM	1.54
HC MASS GRAMS	.507
CO MASS GRAMS	6.407
CO2 MASS GRAMS	19144.82
NOX MASS GRAMS	3.116
CH4 MASS GRAMS	.232
NMHC MASS GRAMS (FID)	.287
FUEL MASS KG	6.032
FUEL ECONOMY MPG (L/100KM)	4.16 (56.60)

1-BAG COMPOSITE RESULTS

HC	G/MI	.057	CH4	G/MI	.026
CO	G/MI	.716	NMHC	G/MI	.032
NOX	G/MI	.348			

FUEL ECONOMY MPG (L/100KM)   4.16 (56.60)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 2.5-R   1-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-5053-001

VEHICLE NUMBER 585   TEST 875-2   GASOLINE EM-0000-F
VEHICLE MODEL 1 FORD VAN   DATE 11/ 7/2001 RUN   FUEL DENSITY 6.176 LB/GAL
ENGINE 6.8 L (415 CID)-   DYNO 5   BAG CART 4   H .133 C .867 O .000 X .000
TRANSMISSION A4   ACTUAL ROAD LOAD ***** HP (86.98 KW)   FTP
ODOMETER 20555 MILES (33072 KM)   TEST WEIGHT 9150 LBS (4149 KG)

BAROMETER 29.39 IN HG (746.5 MM HG)   DRY BULB TEMPERATURE 73.0°F (22.8°C)   NOX HUMIDITY C.F. .923
RELATIVE HUMIDITY 46.4 PCT.

BAG NUMBER	1
BAG DESCRIPTION	
RUN TIME SECONDS	1201.0
DRY/WET CORRECTION FACTOR, SAMP/BACK	.958/.987
MEASURED DISTANCE MILES (KM)	8.94 (14.38)
BLOWER FLOW RATE SCFM (SCMM)	575.9 (16.31)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)
TOTAL FLOW SCF (SCM)	11528. (326.5)
HC SAMPLE METER/RANGE/PPM (BAG)	4.6/ 1/ 4.58
HC BCKGRD METER/RANGE/PPM	4.1/ 1/ 4.06
CO SAMPLE METER/RANGE/PPM	21.0/ 1/ 21.02
CO BCKGRD METER/RANGE/PPM	.6/ 1/ .57
CO2 SAMPLE METER/RANGE/PCT	3.1/ 1/ 3.1311
CO2 BCKGRD METER/RANGE/PCT	.1/ 1/ .0509
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	11.5/ 1/ 11.50
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .17
CH4 SAMPLE PPM (1.101)	2.59
CH4 BCKGRD PPM	2.31
DILUTION FACTOR	4.32
HC CONCENTRATION PPM	1.46
CO CONCENTRATION PPM	19.02
CO2 CONCENTRATION PCT	3.0920
NOX CONCENTRATION PPM	11.36
CH4 CONCENTRATION PPM	.82
NMHC CONCENTRATION PPM	.56
HC MASS GRAMS	.274
CO MASS GRAMS	7.229
CO2 MASS GRAMS	18482.41
NOX MASS GRAMS	6.548
CH4 MASS GRAMS	.178
NMHC MASS GRAMS (FID)	.104
FUEL MASS KG	5.824
FUEL ECONOMY MPG (L/100KM)	4.30 (54.70)

1-BAG COMPOSITE RESULTS

HC	G/MI	.031	CH4	G/MI	.020
CO	G/MI	.809	NMHC	G/MI	.012
NOX	G/MI	.732			

FUEL ECONOMY MPG (L/100KM) 4.30 (54.70)

SOUTHWEST RESEARCH INSTITUTE - DEPARTMENT OF EMISSIONS RESEARCH

COMPUTER PROGRAM LDT 2.5-R   1-BAG EPA FTP VEHICLE EMISSION RESULTS   PROJECT NO. 08-5053-001

VEHICLE NUMBER 585	TEST 875-3	GASOLINE EM-0000-F
VEHICLE MODEL 1 FORD VAN	DATE 11/ 9/2001 RUN	FUEL DENSITY 7.176 LB/GAL
ENGINE 6.8 L (415 CID)-	DYNO 5 BAG CART 4	H .133 C .867 O .000 X .000
TRANSMISSION A4	ACTUAL ROAD LOAD ***** HP (86.98 KW)	FTP
ODOMETER 0 MILES (0 KM)	TEST WEIGHT 9150 LBS (4149 KG)	

BAROMETER 29.45 IN HG (748.0 MM HG)   DRY BULB TEMPERATURE 72.0°F (22.2°C)   NOX HUMIDITY C.F. .929

RELATIVE HUMIDITY 49.3 PCT.

BAG NUMBER	1
BAG DESCRIPTION	
RUN TIME SECONDS	1201.0
DRY/WET CORRECTION FACTOR, SAMP/BACK	.965/.987
MEASURED DISTANCE MILES (KM)	6.87 (11.06)
BLOWER FLOW RATE SCFM (SCMM)	596.6 (16.90)
GAS METER FLOW RATE SCFM (SCMM)	.00 (.00)
TOTAL FLOW SCF (SCM)	11943. (338.2)
HC SAMPLE METER/RANGE/PPM (BAG)	60.6/ 1/ 60.60
HC BCKGRD METER/RANGE/PPM	3.8/ 1/ 3.82
CO SAMPLE METER/RANGE/PPM	****/ 1/1844.00
CO BCKGRD METER/RANGE/PPM	.0/ 1/ .00
CO2 SAMPLE METER/RANGE/PCT	2.3/ 1/ 2.3481
CO2 BCKGRD METER/RANGE/PCT	.0/ 1/ .0447
NOX SAMPLE METER/RANGE/PPM (BAG) (D)	20.9/ 1/ 20.92
NOX BCKGRD METER/RANGE/PPM	.2/ 1/ .19
CH4 SAMPLE PPM (1.101)	10.64
CH4 BCKGRD PPM	1.95
DILUTION FACTOR	5.35
HC CONCENTRATION PPM	57.49
CO CONCENTRATION PPM	1731.75
CO2 CONCENTRATION PCT	2.3118
NOX CONCENTRATION PPM	20.76
CH4 CONCENTRATION PPM	9.05
NMHC CONCENTRATION PPM	47.53
HC MASS GRAMS	11.196
CO MASS GRAMS	681.879
CO2 MASS GRAMS	14315.04
NOX MASS GRAMS	12.476
CH4 MASS GRAMS	2.041
NMHC MASS GRAMS (FID)	9.255
FUEL MASS KG	4.856
FUEL ECONOMY MPG (L/100KM)	4.61 (51.06)

1-BAG COMPOSITE RESULTS

HC	G/MI	1.629	CH4	G/MI	.297
CO	G/MI	99.207	NMHC	G/MI	1.347
NOX	G/MI	1.815			

FUEL ECONOMY MPG (L/100KM) 4.61 (51.06)

Over-Snow Vehicle Sound Level Measurements

Conducted for the Winter Use Plan Supplemental Environmental Impact Statement (SEIS)

for
Yellowstone and
Grand Teton National Parks
and
John D. Rockefeller, Jr.
Memorial Parkway

September 2001

Prepared for:

State of Wyoming
Department of State Parks and Cultural Resources

Prepared by:

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ABSTRACT / INTRODUCTION:

This study of over-snow vehicle sound levels was conducted to provide new and additional information for preparation of the Winter Use Plan Supplemental Environmental Impact Statement (SEIS) for Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway. The pass-by sound level of a variety of over-snow vehicles was measured at operational speeds that would be experienced under normal use of the vehicles while in the national park units. The pass-by testing included four different types of snow coaches and various models of snowmobiles. All testing was conducted on the same day in the same location with the same terrain and background conditions.

This study is intended to supplement a previous study commissioned by the National Park Service entitled "Technical Report on Noise: Winter Use Plan Final Environmental Impact Statement"(1). This report bears the number "HMMH Report No.295860.18", and was written and submitted by Harris Miller Miller & Hanson, a noise and vibration consulting firm located in Burlington, Massachusetts. Much work in that study concentrated on calculating the threshold of audibility of various vehicle types in various types of terrain and background noise conditions. The sound levels assigned to the various vehicle types were general in nature. This report is not intended to conflict with nor supplant the report indicated above, but rather, may be used to supplement the general information used in the FEIS report with more specific sound data regarding various vehicle types.

Due to time constraints associated with producing the SEIS, it was necessary to perform the sound testing on a grass surface rather than on a snow surface where these over-snow vehicles are normally operated. However, grass is an acceptable substitute under Society of Automotive Engineers (SAE) testing protocol guidelines. Therefore, a testing series was planned and implemented in West Yellowstone, Montana on September 13, 2001. Eighteen different snowmobiles were tested for sound emissions, along with four different types of snow coaches and two common wheeled road vehicles.

The testing for the snowmobiles was conducted at three different operational speeds – 20, 35, and 45 mph. These speeds are reflective of the normal operational speeds in congested areas and permitted speeds while operated on the park snow roads. During the testing, it was discovered most of the snow coaches could not safely reach the higher target test speeds. Consequently, the snow coaches and conversion vans were tested according to their individual capability. Test speeds for the snow coaches are reported in the results table.

TESTING PARAMETERS:

The Code of Federal Regulations (CFR) addresses the issue of sound emissions from snowmobiles and snowplanes, but does not address sound emissions from snowcoaches. 36 CFR 2.18 Snowmobiles: states, "maximum A-weighted pass-by sound levels at a distance of 50 feet (15.2m) under full throttle shall be a maximum of 78 dB(A) for snowmobiles." 36 CFR 7.21 and 7.22 specify "maximum sound emission levels at 50 feet under full throttle from snowmobiles at 78 dB(A) and from snowplanes at 86 dB(A). The CFR regulations say nothing substantial about how the measurements are to be taken.

Test procedures for the measurement of snowmobile sound emissions have been established by SAE and are outlined by SAE Standard J1161, Mar83. The basic layout for the test track, speed at which the test is to be made, and basic operational considerations for the instrumentation are enumerated in this Standard. This Standard is in conflict with the CFR regulation in that the Standard specifies a speed of 15 mph (24 kph). There is an additional SAE Standard, J-192, which provides for the sound level measurement of snowmobiles while being operated at full throttle. The sound testing for the Clean Snowmobile Challenge 2001 SAE design competition used both standards for the layout and testing of the sound level of the competing snowmobiles under maximum acceleration conditions. The general procedure as described in SAE 2001-01-3652 (2) was used for this testing, with testing being conducted at steady state speeds.

Testing for the snowmobiles was done at speeds of 20, 35, and 45 mph. The 20 mph speed represents speeds likely to be encountered in congested areas, such as around Old Faithful in Yellowstone Park. The 35 mph speed is the speed limit suggested by the State of Wyoming for the road segments from West Yellowstone to Old Faithful. The 45 mph speed is the speed limit on other Park roads. Two skilled and experienced recreational riders drove all of the test runs.

The eighteen snowmobiles tested included one 4-stroke model, a 2001 Arctic Cat 4-stroke, and seventeen different two-stroke models. The two-stroke models tested included one snowmobile with a modified exhaust system (2001 Polaris 800 RMK with a Starting Line Products single pipe) for comparison purposes. All other snowmobiles had stock exhaust systems. All four major snowmobile manufacturers were represented in the testing (Polaris: 7 sleds, Arctic Cat: 4 sleds, Ski Doo: 4 sleds, Yamaha: 3 sleds). It should be noted that the only four-stroke model that was available at the time of testing (due to time constraints of the SEIS process) was the 2001 Arctic Cat 4-stroke prototype. While both Arctic Cat and Polaris have 2002 production four-stroke models available, neither had come off the production line at the time of this testing.

The four snow coaches tested included two conversion vans (one Ford equipped with front skis and a rear track and one Chevy equipped with Mattracks), a Prinoth articulated snow coach, and a Bombardier with rear exhaust. None of the snow coaches had working speedometers, so an observer inside the coach equipped with a GPS determined coach speeds. This particular GPS, a Garman GPS III, had been checked with police traffic radar for accuracy.

In addition, full throttle acceleration tests were done with two snowmobiles. The Arctic Cat Four-Stroke was tested along with a Polaris Sport Touring machine. The Polaris was the control sled used during the CSC 2001 competition. The Polaris had a peak average reading of 78 dB(A) during this testing as well as during the CSC 2001 testing, indicating a close correlation between the testing on snow and the current testing on a grass surface. The two road vehicles were tested under the same conditions.

The test track was set up at the old airport site just outside of West Yellowstone, Montana. The test track dimensions were pursuant to SAE J1161 for a bi-directional test site layout. The surface of the old airport runway was sparse grass over dirt. The surface was not ideal, but the testing correlated closely with the control sled data gathered during the CSC 2001.

SUMMARY OF PROCEDURES:

1. Test track layout and instrumentation as described in SAE J1161 and J-192.
2. Three runs in each direction were done at each listed speed; the dBA level reported in the results table is the average of the three runs.
3. A total of 416 separate sound level measurements were taken over the course of the testing.
4. Full throttle testing of the control snowmobile showed close correlation with the CSC 2001 test conditions.

TEST RESULTS AND CONDITIONS:

Testing was done on September 13, 2001 at the old airport in West Yellowstone, Montana. A test track was prepared according to SAE J1161 and J-192. The day started out ideal for testing. Skies were partly cloudy. The temperature was in the range of 52ºF to 75ºF. Winds during testing were calm to about 10 mph. The surface surrounding the track was sparse grass covering dirt. The test area was level and free of any trees. The elevation of the test site was 6740 feet above sea level from GPS data. Uncorrected barometric pressure was 23.61 inches Hg by GPS, and the relative humidity was 70% to 80%. A cold front with thunderstorm moved through the area in the late afternoon. Testing was suspended until after the storm passed.

The instrument used for the testing was a Quest Technologies M2100, #DAA070020. The instrument was allowed to equilibrate to ambient temperature for the time it took to set up the test course. The instrument was calibrated using the calibrator supplied with the instrument, with appropriate corrections for ambient conditions. The calibration was checked each hour.

The instrument was set up 50 feet (15.2m) from the track centerline. The instrument was oriented horizontally, with the microphone set 60 inches (1.52m) above the surface. The windshield was in place. Background noise was between 34 to 42 dBA. The testing took place between 8:00AM to 7:00PM. Results are presented in the following tables:

SOUND MEASURMENT TABLES:

Tables 1 through 3 display average sound levels measured for the 18 different snowmobiles at the various speeds. Table 4 provides a comparison of the sound levels measured for the Arctic Cat 4-stroke, the Polaris control sled from the CSC 2001, the sound level winning entry from the CSC 2001, and two SUV's. Table 5 displays average sound levels measured for the four different snowcoaches. Table 6 provides a comparison of stock snowmobile sound level measurements looking at: displacement, mileage, fan cooled, two-stroke, four-stroke and brand. A complete listing of all sound measurements recorded may be found in Appendix I.

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right	Sound Left
Snowmobile with Modified Exhaust	Polaris 388 mi	RMK 800	'01	4XASM8BS41C155135	800 Liquid cooled, SLP single pipe, 151x2	20	80.5	**81.9**
						35	80.2	80.5
						45	80.5	80.4
Snowmobile	Polaris 1711 mi	RMK 800	'00	4XASR8BS64B874428	800 Liquid cooled, 156x2	20	73.2	72.9
						35	74.3	74.0
						45	77.7	77.0
Snowmobile	Polaris 1902 mi	RMK 700	'01	4XASM7ASX1C160030	700 Liquid Cooled, 144x2	20	70.9	70.0
						35	76.0	76.1
						45	76.7	76.5
Snowmobile	Polaris 4143 mi	RMK 600	'01	4XASR6OSX1C160505	600 Liquid Cooled, 136x2	20	69.7	68.6
						35	73.8	**73.2**
						45	76.6	76.6
Snowmobile	Polaris 3591 mi	RMK 500	'01	4XASR5ASI1C160679	500 Liquid Cooled, 136x1 1/2	20	69.4	69.5
						35	74.2	74.6
						45	**75.6**	75.7
Snowmobile (Control sled for CSC 2001)	Polaris 5438 mi	Sport Touring	'01	4XASD5B571C161445	550 Fan Cooled, 136x7/8	20	73.7	70.5
						35	77.7	76.9
						45	78.5	77.3

Table 1: Average Pass-By Measurements for Individual Polaris Snowmobiles

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right	Sound Left
Snowmobile	Polaris 4486 mi	Indy Trail	'99	4XAEB4ES7XC080768	488 Fan Cooled, 121x7/8	20	70.3	71.2
						35	76.0	75.5
						45	76.9	76.5
Snowmobile	Arctic Cat 483 mi	Mt. Cat	'01	4UF01SNW01T129371	800 Liquid cooled, 136x2	20	75.0	72.3
						35	75.4	76.0
						45	77.0	76.7
Snowmobile	Arctic Cat 4071 mi	Four Stroke	'01	4UF01SNW91T159520	660 Liquid Cooled four cycle, 136x1/2	20	**67.3**	**68.2**
						35	73.8	74.4
						45	76.1	76.3
Snowmobile	Arctic Cat 550 mi	Mt. Cat	'01	4UF01SNW21T125192	600 Liquid Cooled, 136x2	20	71.7	71.9
						35	**73.3**	74.6
						45	75.7	**75.3**
Snowmobile	Arctic Cat 1402 mi	Cougar	'97	9706911	550 Liquid Cooled, 136x7/8	20	74.0	71.0
						35	76.9	78.0
						45	78.0	79.6
Snowmobile	Ski-Doo 1651 mi	Summit 700	'01	2BPS175641V000027	700 Liquid Cooled, 136x2	20	73.0	73.6
						35	77.4	77.3
						45	79.6	**79.8**

Table 2: Average Pass-By Measurements for Individual Polaris, Arctic Cat and Ski Doo Snowmobiles

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right	Sound Left
Snowmobile	Ski-Doo 535 mi	Summit 600	'01	2BPS176101V000206	600 Liquid Cooled, 136x2	20	71.0	70.6
						35	76.8	76.9
						45	77.1	76.6
Snowmobile	Ski-Doo 4185 mi	Touring 500F	'01	2BPS180511V000152	500 Fan Cooled, 136x7/8	20	72.4	71.3
						35	77.3	76.7
						45	78.1	78.8
Snowmobile	Ski-Doo 3219 mi	MXZ	'00	2BPS1566YV000469	440 Fan Cooled, 121x1/2	20	74.9	72.4
						35	76.6	76.0
						45	77.0	75.5
Snowmobile	Yamaha 1512 mi	700 Mt. Max	'01	8ED011931	700 Liquid Cooled, 141x2	20	70.8	70.1
						35	75.6	74.1
						45	77.1	77.3
Snowmobile	Yamaha 2252 mi	600 Mt. Max	'00	8EJ001205	600 Liquid Cooled, 141x2	20	72.5	70.3
						35	75.2	73.5
						45	77.3	76.3
Snowmobile	Yamaha 1270 mi	600 Mt. Max	'99	8CS006586	600 Liquid Cooled, 136x1 1/2	20	71.2	69.7
						35	76.0	75.5
						45	76.9	76.5

Table 3: Average Pass-By Measurements for Individual Ski Doo and Yamaha Snowmobiles

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right	Sound Left
Snowmobile	Arctic Cat 4071 mi	Four Stroke	'01	4UF01SNW01T129371	660 Liquid Cooled four cycle, 136x1/2	Full Throttle Acceleration J-192	78.3	78.3
Snowmobile (CSC 2001 Control Sled)	Polaris 5438 mi	Sport Touring	'01	4XASD5B571C161445	550 Fan Cooled, 136x7/8	Full Throttle Acceleration J-192	78.7	78.0
Snowmobile (CSC 2001 Control Sled)	Polaris 5438 mi	Sport Touring	'01	4XASD5B571C161445	550 Fan Cooled, 136x7/8	Full Throttle Acceleration J-192 During CSC 2001	78.0	
Snowmobile Kettering University Entry CSC 2001	Yamaha Chassis	Custom	N/A	N/A	659 cc Daihatsu Turbocharged four cycle	Full Throttle Acceleration J-192 During CSC 2001	**72.0**	
Pickup Truck	Dodge	3500	'01	1BTMF33611J255429	Cummins Turbo-Diesel	Acceleration	74.9	73.3
						35	68.5	68.2
						45	**71.9**	69.6
Sport Utility Vehicle	Chevrolet	Suburban 2500	'01	3GNGK26U41G103683	6.0L Gasoline V-8	Acceleration	70.1	68.4
						35	62.7	63.1
						45	64.8	64.4

Table 4: Comparison of Average Pass-By and Full Acceleration Measurements for Arctic Cat 4-Stroke, CSC 2001 Polaris Control Sled, CSC 2001 Sound Category Winner and two Trucks

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right	Sound Left
Articulated Tracked Snow Coach	Prinoth	N/A	N/A	N/A	5.2L Chrysler V-8 w/auto transmission	21 Measured with GPS Onboard	79.6	80.4
Conversion Van - Front Skis, Rear Track	Ford	E350	'00	1FBSS31S9VHA03291	Gasoline V-10 with Auto Transmission	20	73.9	71.9
						25	76.1	**81.3**
						Speed Measured with GPS onboard		
Conversion Van – Four Tracks (Mattrack)	Chevrolet	3500	'99	1GAHG39FXX1036234	6.5L Turbo-Diesel w/ Auto Transmission	22	74.0	74.7
						32	**78.0**	79.0
						Speed Measured with GPS onboard		
Snow Coach	Bombardier	B-12	'81	101810085	5.2L Chrysler V-8 Rear Exhaust	20	**69.9**	**71.5**
						30	79.9	**78.0**
						Speed Measured with GPS onboard		

Table 5: Average Pass-By Measurements for Individual Snowcoaches

Stock Snowmobile Sound Levels by Category			
Category	Speed		
Displacement	**20**	**35**	**45**
500 cc or less	71.4	75.8	76.8
501 – 699 cc	71,1	75.6	77.0
700-799 cc	71.4	76.1	77.8
800 cc	73.3	74.9	77.1
Mileage			
0-1000	72.0	75.5	76.4
1000 - 3000	71.6	75.7	77.6
3000 and up	70.7	75.5	76.8
Fan Cooled	72.1	76.6	77.3
All Two Stroke	71.9	75.5	77.3
Four Stroke	67.7	74.1	76.2
Brand			
Polaris	70.8	75.2	76.8
Arctic Cat	71.4	75.3	76.8
Ski-Doo	72.4	76.9	77.8
Yamaha	70.8	75.0	76.9
All	71.4	75.6	77.1

Table 6: Stock Snowmobile Average Sound Level Comparisons

ANALYSIS OF RESULTS:

Table 6 is a summary listing of the average sound levels generated by the snowmobiles during this test series. The results are broken into various categories to answer the following questions: Does engine displacement make a difference in the sound level generated? Do snowmobiles get louder as more miles are put on them? Are fan-cooled snowmobiles quieter or louder than liquid-cooled sleds? Is there a significant difference between the sound levels of two-stroke and four-stroke snowmobiles? and Are there noticeable differences between the four major brands of snowmobiles?

As one may see from Table 6, the sound levels are quite uniform across the board, regardless of the category chosen. Sound levels were generally consistent when comparing displacement categories at the various speeds. While the 800 cc class was slightly louder at 20 mph, it was actually the quietest at 35 mph and as quiet as the other engine sizes at 45 mph. When comparing snowmobiles with few miles of use versus over 3,000 miles of use, the ones with more miles were either quieter or as quiet as the new sleds. Fan cooled machines were only marginally louder than average, regardless of the reputation these machines may have for being significantly louder than the liquid cooled versions.

The Arctic Cat Four-Stroke tested was an early production model, introduced to address the sound and emission concerns being debated. Essentially, Arctic Cat adapted a liquid cooled four-cycle small automobile engine to the snowmobile chassis. This is a similar tactic to that taken by the Kettering University team in the CSC 2001 competition. As a category, the Arctic Cat Four-Stroke was the quietest over-snow vehicle tested. Still, the machine generated a higher sound level at 35 and 45 mph than was expected, considering the experience with the Kettering University machine during the CSC 2001. Observers of the Arctic Cat Four-Stroke runs generally commented the increased noise at 35 and 45 mph was largely mechanical and emanated from the track and the skis, rather than from the engine. This was also generally true of several of the more quiet two-stroke snowmobiles tested.

The HMMH Report conducted for the FEIS tested four snowmobiles during their research. All of these were of 500 cc displacement. Cooling type was not addressed. If the snowmobile data from the HMMH Report is compared to this new data (hereafter referred to as the JHSI Report), there is close if not identical correlation at 20 mph to the 500 cc machines tested for the JHSI Report. As speeds increased, the sound levels measured for the JHSI Report were higher than those stated in the HMMH Report. At 40 mph, the HMMH Report finding was 73.9 dB(A). Using the same type of linear regression model as used in the HMMH Report, the data in the JHSI Report is about 2 dB(A) higher at 40 mph. In essence, the slope of the regression line for the snowmobile data is steeper for the JHSI Report than in the HMMH Report.

Some may argue the testing surface for the JHSI Report was the cause of the louder readings than those measured in the HMMH Report. To address this issue, the Polaris snowmobile used as the control sled during the CSC 2001 competition was run through a maximum acceleration test series just as it was run during the CSC 2001. In both cases the sound level measured, rounded to the nearest integer, was 78 dB(A). While this is not definitive, it does suggest there is close correlation to the data gathered on the snow surface.

Four different types of snowcoaches were tested for the JHSI Report. These are listed in Table 5. Testing for the JHSI Report showed significantly higher sound levels for snowcoaches than those reported in the HMMH Report. Again, correlations at 20 mph using the regression model from the HMMH Report are quite close, at least for the

Bombardier. As speeds increased, the variation between the HMMH Report data and the JHSI Report data became more pronounced. For example, the Bombardier sound level at 30 mph was reported in the HMMH Report at 74.6 dB(A). Data generated during this testing (JHSI) reported an average sound level at 30 mph of 78.9 dB(A). The divergence of the data was greatest when the sound levels for the four-track conversion van are compared. At 30 mph, the HMMH study reported a sound level of 69.7 dB(A). The four-track van tested for the JHSI Report produced a sound level of 78.5 dB(A) at 32 mph. This is a significant difference. The Ford two-track conversion van recorded the loudest sound level of any stock vehicle during its testing. The primary reason for this was the loud "hissing" exhaust sound made during the runs at 25 mph, which was the maximum speed for this snow coach.

The HMMH Report mentions using vehicle speedometers in the snowcoaches for speed determination. None of the snow coaches tested for the JHSI Report had working speedometers, which is why the GPS unit was used to determine actual ground speed.

SUMMARY:

The loudest stock over-snow vehicle was a Ford two-track conversion van, which registered an average peak of 81.3 dB(A). The loudest stock snowmobile was a Ski-Doo Summit 700, which had a peak reading of 79.8 dB(A) at 45 mph. A modified Polaris RMK 800 was the loudest vehicle tested overall, with a peak average reading of 81.9 dB(A).

The quietest over-snow vehicle tested was the Arctic Cat Four-Stroke touring snowmobile at 20 mph. Its lowest average reading at this speed was 67.3 dB(A). Several other snowmobiles were in this range of the high 60's to low 70's at the 20 mph speed. The Bombardier snow coach had a low average reading at 20 mph of 69.9 dB(A), making it the quietest of the snow coaches at this speed.

These data show the sound levels of many late model snowmobiles overlap or are quieter than snow coaches under the same or similar testing conditions. The quietest snowmobile at 20 mph produced less sound than any of the snow coaches at the same speed. None of the over-snow vehicles were as quiet as the wheeled road vehicles tested, although the Dodge diesel pickup was near the lower level of the snowmobile sound envelope.

The Arctic Cat Four-Stroke was subjectively considerably quieter at 20 mph than any other over-snow vehicle. This may be due to the fewer exhaust pulses at a given RPM as well as the clutching engagement tailored to the four-cycle engine. As the testing speed increased for this snowmobile, the mechanical sound of the track and under damped skis overcame the engine sound level. One observation is that this higher level of track and ski noise may be generated because of: 1) the blow molded plastic skis on this particular snowmobile model versus a thinner profile plastic ski which appeared to generate less sound on other models, and 2) more noise and vibration emanating from the track, perhaps due to track tension, lug height, or other factors associated with track noise . Because of this, the Arctic Cat Four-Stroke was not the quietest snowmobile at speeds of 35 and 45 mph.

The lowest average reading for a snowmobile at 35 mph was the Polaris 600 RMK, with a sound level of 73.2 dB(A). The lowest average reading for a snowmobile at 45 mph was 75.3 dB(A) by the Arctic Cat Mt. Cat 600. Both of these machines are liquid cooled. As an aside, the sound level recorded during normal dinner conversation after the testing was 78 dB(A).

The lowest average reading for a snow coach at a nominal 30 mph is 78.0 dB(A). Both the Chevrolet / Mattrack conversion van and the Bombardier B-12 snow coach recorded these sound levels.

For comparison, the Kettering University entry in the CSC 2001 competition recorded a sound level of 72 dB(A) during the maximum acceleration event. We would expect its sound level during steady state operation to be considerably lower than this.

Quiet snowmobiles already exist, as shown by these data. The technology is improving to make these machines even quieter than they are now. Work will need to be done not only with engine sound levels, but also with the mechanical sound generated by the track and skis, regardless of whether the over-snow vehicle is a snowmobile or a snowcoach. This work is going forward with the Clean Snowmobile Challenge as well as by the various snowmobile manufacturers.

The technology appears to exist to require that over-snow vehicles meet reasonable sound regulations. However, any regulations written should reasonably consider that over-snow vehicle sound levels are not attributable just to engine sounds but also must factor in the other mechanical sounds associated with tracked vehicles. Additionally, any arguments for banning snowmobiles because of excessive noise will be based upon emotional rather than scientific reasons since under the excessive sound level argument, snowcoaches would have to be banned as well because they are noisier than snowmobiles.

ACKNOWLEDGEMENTS

The State of Wyoming and the author wish to acknowledge and thank the following businesses and entities that provided vehicles for the sound level measurements in this study:

Alpen Guides – Bombardier snowcoach
Amfac Parks & Resorts/Yellowstone National Park Lodges – Prinoth snowcoach
Flagg Ranch Resort – 4-track/Mattrack Conversion Van
Polaris West – Polaris snowmobiles
Three Bear Lodge – Front Skis/Rear Track Conversion Van
Wyoming Trails Program – SUV's and snowmobiles
Yellowstone Adventures – Ski Doo snowmobiles
Yellowstone Arctic-Yamaha – Arctic Cat and Yamaha snowmobiles

We would also like to thank the test riders, Kelly Wells and Ben Adams, for their tireless and invaluable assistance in conducting the 416 sound level measurements for this study.

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Appendix 1
Raw Data Tables
of
Vehicle Sound
Pass-By Measurements

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Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right			Sound Left		
Snowmobile with Modified Exhaust	Polaris 388 mi	RMK 800	'01	4XASM8BS41C155135	800 Liquid cooled, SLP single pipe, 151x2	20	80.4	79.6	81.6	**83.5**	**79.1**	**83.1**
						35	79.3	80.6	80.6	80.3	79.9	81.4
						45	78.9	81.3	81.8	79.3	81.8	80.0
Snowmobile	Polaris 1711 mi	RMK 800	'00	4XASR8BS64B874428	800 Liquid cooled, 156x2	20	73.1	73.7	72.9	72.7	73.5	72.7
						35	74.3	74.3	74.3	74.3	73.7	74.0
						45	78.4	77.4	77.4	76.5	77.2	77.3
Snowmobile	Polaris 1902 mi	RMK 700	'01	4XASM7ASX1C160030	700 Liquid Cooled, 144x2	20	70.3	71.2	71.1	70.4	69.4	70.3
						35	76.0	75.2	76.8	75.3	76.6	76.3
						45	77.1	77.0	76.1	76.6	76.6	76.2
Snowmobile	Polaris 4143 mi	RMK 600	'01	4XASR6OSX1C160505	600 Liquid Cooled, 136x2	20	69.9	69.4	69.9	68.5	68.9	68.3
						35	73.8	73.8	73.7	**73.2**	**73.2**	**73.2**
						45	76.5	76.9	76.4	77.2	75.6	76.9
Snowmobile	Polaris 3591 mi	RMK 500	'01	4XASR5ASI1C160679	500 Liquid Cooled, 136x1 1/2	20	68.4	70.0	69.7	70.3	69.1	69.1
						35	74.2	74.2	74.2	73.6	75.8	74.4
						45	**74.7**	**76.3**	**75.8**	75.7	75.3	76.1
Snowmobile (Control sled for CSC 2001)	Polaris 5438 mi	Sport Touring	'01	4XASD5B571C161445	550 Fan Cooled, 136x7/8	20	75.0	74.0	72.0	69.6	70.7	71.3
						35	77.0	78.3	77.7	77.6	76.4	76.8
						45	80.1	77.5	77.8	77.2	77.0	77.6

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right			Sound Left		
Snowmobile	Polaris 4486 mi	Indy Trail	'99	4XAEB4ES7XC080768	488 Fan Cooled, 121x7/8	20	70.6	70.1	70.1	69.2	69.9	70.9
						35	77.0	78.3	77.7	77.6	76.4	76.8
						45	80.1	77.5	77.8	77.2	77.0	77.6
Snowmobile	Arctic Cat 483 mi	Mt. Cat	'01	4UF01SNW01T129371	800 Liquid cooled, 136x2	20	75.1	75.3	74.6	73.3	72.2	71.3
						35	75.5	74.9	75.7	76.2	75.7	76.1
						45	76.8	76.8	77.5	76.5	77.0	76.6
Snowmobile	Arctic Cat 4071 mi	Four Stroke	'01	4UF01SNW91T159520	660 Liquid Cooled four cycle, 136x1/2	20	**66.4**	**67.6**	**68.0**	**68.6**	**68.2**	**67.8**
						35	74.3	73.4	73.6	72.9	75.2	75.0
						45	76.3	76.6	75.4	76.4	77.3	75.3
Snowmobile	Arctic Cat 550 mi	Mt. Cat	'01	4UF01SNW21T125192	600 Liquid Cooled, 136x2	20	70.4	71.7	73.1	71.3	72.1	72.3
						35	**73.0**	**73.2**	**73.6**	75.5	73.9	74.3
						45	75.7	75.2	76.2	**75.4**	**75.2**	**75.4**
Snowmobile	Arctic Cat 1402 mi	Cougar	'97	9706911	550 Liquid Cooled, 136x7/8	20	74.4	73.6	74.4	70.2	71.1	71.9
						35	76.7	77.3	76.8	78.1	78.1	77.9
						45	77.5	77.6	79.0	79.7	79.7	79.4
Snowmobile	Ski-Doo 1651 mi	Summit 700	'01	2BPS175641V000027	700 Liquid Cooled, 136x2	20	71.1	73.2	74.9	72.8	72.5	75.4
						35	78.1	77.7	76.4	77.6	77.5	76.7
						45	79.4	79.6	79.7	**80.0**	**80.1**	**79.3**

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right			Sound Left		
Snowmobile	Ski-Doo 535 mi	Summit 600	'01	2BPS176101V000206	600 Liquid Cooled, 136x2	20	70.4	71.3	71.2	70.5	70.9	70.5
						35	75.8	77.6	77.0	76.8	77.6	76.4
						45	76.6	76.7	78.0	75.8	77.3	76.7
Snowmobile	Ski-Doo 4185 mi	Touring 500F	'01	2BPS180511V000152	500 Fan Cooled, 136x7/8	20	73.1	72.1	72.1	71.6	71.1	71.2
						35	76.8	78.7	76.4	76.9	76.4	76.8
						45	77.0	78.4	78.9	79.0	78.6	78.8
Snowmobile	Ski-Doo 3219 mi	MXZ	'00	2BPS1566YV000469	440 Fan Cooled, 121x1/2	20	73.0	75.3	76.4	71.9	72.8	72.6
						35	76.7	77.0	76.1	76.3	75.8	76.1
						45	78.2	76.1	76.9	75.0	75.6	75.8
Snowmobile	Yamaha 1512 mi	700 Mt. Max	'01	8ED011931	700 Liquid Cooled, 141x2	20	70.4	71.3	70.8	70.3	69.6	70.4
						35	75.6	75.4	75.9	74.6	74.1	73.7
						45	78.3	76.4	76.7	76.8	77.7	77.3
Snowmobile	Yamaha 2252 mi	600 Mt. Max	'00	8EJ001205	600 Liquid Cooled, 141x2	20	70.6	72.5	74.3	69.1	71.1	70.8
						35	74.8	75.8	75.0	72.8	74.5	73.2
						45	77.2	76.4	78.4	76.0	76.5	76.4
Snowmobile	Yamaha 1270 mi	600 Mt. Max	'99	8CS006586	600 Liquid Cooled, 136x1 1/2	20	71.8	70.9	71.1	69.4	69.8	69.8
						35	75.5	75.8	76.9	75.3	75.6	75.6
						45	77.6	77.2	76.0	76.4	76.8	76.3

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/ Track	Speed	Sound Right			Sound Left		
Snowmobile	Arctic Cat 4071 mi	Four Stroke	'01	4UF01SNW01T129371	660 Liquid Cooled four cycle, 136x1/2	Full Throttle Acceleration J-192	78.2	79.1	77.6	79.0	78.3	77.6
Snowmobile (CSC 2001 Control Sled)	Polaris 5438 mi	Sport Touring	'01	4XASD5B571C161445	550 Fan Cooled, 136x7/8	Full Throttle Acceleration J-192	78.7	78.4	78.9	77.6	78.4	78.0
Snowmobile (CSC 2001 Control Sled)	Polaris 5438 mi	Sport Touring	'01	4XASD5B571C161445	550 Fan Cooled, 136x7/8	Full Throttle Acceleration J-192 During CSC 2001	78.0					
Snowmobile Kettering University Entry CSC 2001	Yamaha Chassis	Custom	N/A	N/A	659 cc Daihatsu Turbocharged four cycle	Full Throttle Acceleration J-192 During CSC 2001	72.0					
Pickup Truck	Dodge	3500	'01	1BTMF33611J255429	Cummins Turbo-Diesel	**Acceleration**	74.2	74.7	75.8	73.3	73.6	72.9
						35	67.4	68.5	69.5	66.5	69.6	68.4
						45	71.1	73.3	71.3	69.5	70.6	68.8
Sport Utility Vehicle	Chevrolet	Suburban 2500	'01	3GNGK26U41G103683	6.0L Gasoline V-8	**Acceleration**	69.4	70.2	70.6	68.6	68.3	68.4
						35	62.5	62.8	62,7	61.1	61.5	66.6
						45	65.0	64.8	64.6	63.6	63.5	66.0

Vehicle Type	Make/Mileage	Model	Year	VIN	Engine/Track	Speed	Sound Right			Sound Left		
Articulated Tracked Snow Coach	Prinoth	N/A	N/A	N/A	5.2L Chrysler V-8 w/auto transmission	21 Measured with GPS Onboard	80.1	79.0	79.7	80.2	80.7	80.3
Conversion Van - Front Skis, Rear Track	Ford	E350	'00	1FBSS31S9VHA03291	Gasoline V-10 with Auto Transmission	20	73.2	74.6	73.8	73.5	71.1	71.2
						25	**77.4**	**76.1**	**74.8**	**80.6**	**81.7**	**81.5**
						Speed Measured with GPS onboard						
Conversion Van – Four Tracks (Mattrack)	Chevrolet	3500	'99	1GAHG39FXX1036234	6.5L Turbo-Diesel w/ Auto Transmission	22	74.9	73.8	73.2	75.8	73.8	74.4
						32	77.5	78.2	78.5	79.8	79.0	78.4
						Speed Measured with GPS onboard						
Snow Coach	Bombardier	B-12	'81	101810085	5.2L Chrysler V-8 Rear Exhaust	**20**	**70.1**	**69.8**	**69.8**	**71.4**	**70.4**	**72.7**
						30	**82.1**	**76.8**	**80.9**	**76.4**	**76.2**	**81.3**
						25	**73.7**			**74.2**		
						Speed Measured with GPS onboard						

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APPENDIX 2

Photos
Of
Sound Testing and Over-Snow Vehicles

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Photo 1 – Test Course

Photo 2 – Test Snowmobiles

Photo 3 – 2-Stroke on Test Course

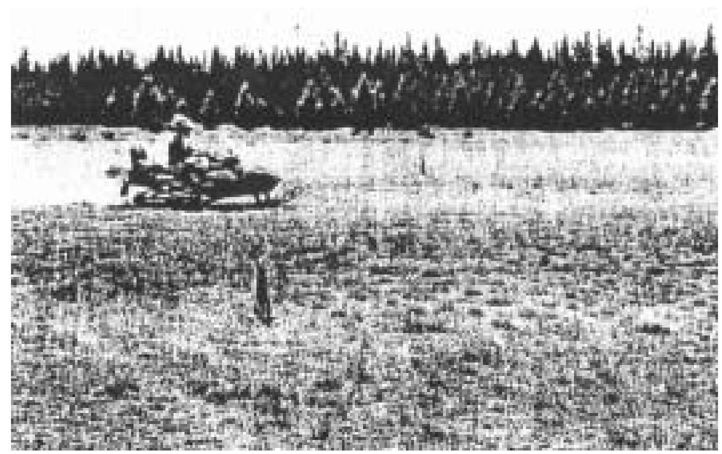

Photo 4 – 4-Stroke on Course

Photo 5 – Test Snowmobiles

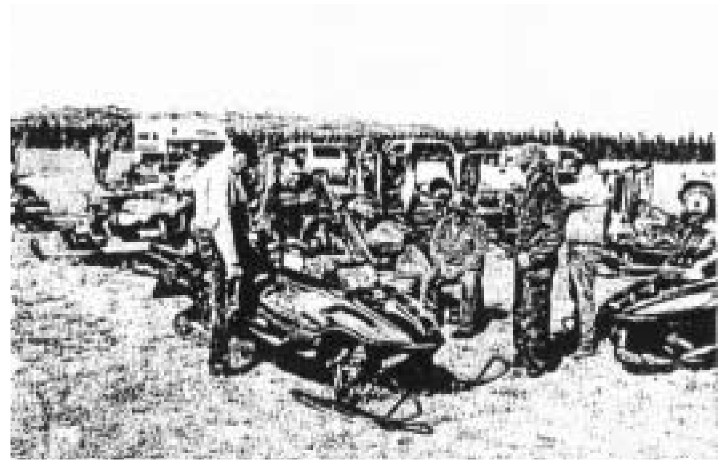

Photo 6 – Test Snowmobiles

Photo 7 – Prinoth Snowcoach

Photo 8 – Bombardier Snowcoach

Photo 9 – Two-Track Conversion Van

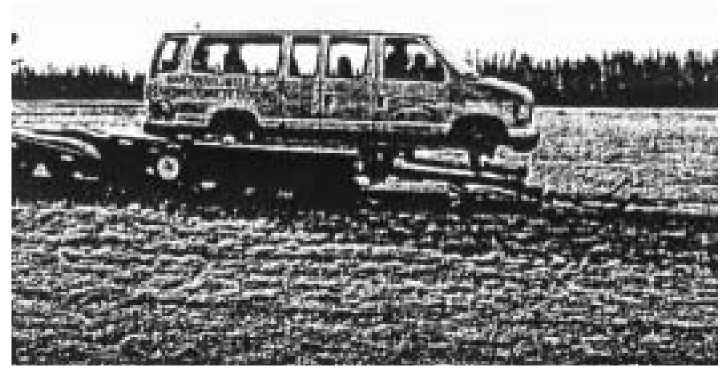

Photo 10 – Two-Track Conversion (close up)

Photo 11 – Mattrack Conversion Van

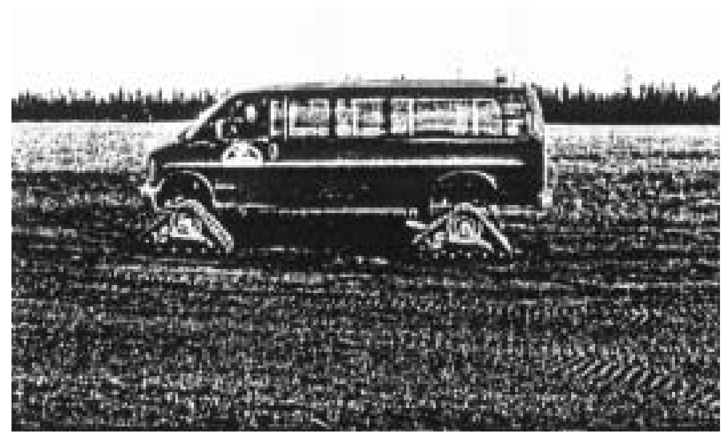

Photo 12 – Mattrack (close-up)

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- EPA - Direct Import vehicle program (vehicle conversion, testing & documentation)
- BMW - Vehicle Reality testing
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- ASM -- tests
- NMOG –tests
- Shed-Evaporative tests (conventional/variable volume)
- Highway Fuel Economy Tests (HFET)
- Evaporative Canister Loading
- Exhaust gas speciation collection & analysis
- Inspection and maintenance (I/M) tests
- Japan 10/11 tests
- ECE 111560 (European)
- CAP-2000- procedures
- On-Board-Diagnostic (OBD) tests
- Mileage Accumulation tests
- Executive Order (testing/application)

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History Behind the AFT Carburetor

Since the beginning of the combustion engine, man has had a natural desire to get as much power out of the wide variety of motors manufactured for work and play. For the past 37 years, William "Red" Edmonston has chosen the motorcycle as his passion for power and speed.

Red started racing Triumph motorcycles in the 1940's and after 13 years of racing and breaking bones, he decided to move to California and work with Triumph as a road manager as well as open a Honda dealership to provide for his young family. During the 1960's, Red continually became frustrated with the fuel delivery systems for the motorcycle industry. Most of the carburetors being manufactured and sold on motorcycles were complex to tune, and required a constant effort to keep tuned for proper operation of the motor. This was primarily because of the multiple and overlapping circuits (different jets for the differing throttle positions) that caused the air fuel mixture to be very rich at different throttle positions. These early carburetors could not adapt for altitude changes either, which added to the constantly differing air-to-fuel ratios and tuning problems. Besides the frustrations that many had with keeping their motorcycles running at optimum, these crude fuel delivery systems also cause the motor to run very inefficiently and with significant harmful emissions.

In the late 196o's, after many years of racing, managing race teams, and selling motorcycles, Red began his long career of inventing, designing, and manufacturing carburetors for the motorcycle industry. In short, Red has had a significant impact on the motorcycle industry over the past 40 years. Red has held nearly 100 patents and has invented and manufactured nine different carburetors, each of which has shared some similarities while each subsequent model continually added improvements in functionality and performance. The history of the Red Edmonston' carburetors spans many years and a great deal of experience and improvements:

- 1968-1969: The Lake Injector prototype and final production model carburetor.
- 1970-1971: The Pos-A-Fuel prototype and final production model carburetor.
- 1971: The Pos-A-Fuel with remote float bowl production model carburetor.
- 1973-1974: The Lectron prototype and final production model carburetor.
- 1976-1977: The E.I. Prototype and final production model carburetor.
- 1978: The Blue Magnum production model carburetor.
- 1980: The Bank of Four Blue Magnum model carburetor.
- 1981-1982: The Qwik Silver prototype and production model carburetor.

- 1982: The Qwik Silver Bank of Four carburetor wins Daytona super-bike race.
- 1993: The QwikSilver II production model carburetor.
- 1995: The QwikSilver II was sold to the Edelbrock Corporation
- 1997: Red resigned from Edelbrock/QwikSilver to begin development on a new two-stroke carburetor.
- 1998 The new AFT Two-Stroke Carburetor was tested on a 1997 Honda CR250 and met California's new strict off-road emissions standards, over a 90% reduction in emissions.
- 2000 The new AFT Two-Stroke Carburetors were test on a Polaris 550 Snowmobile and produced an 80% Reduction in emissions.
- June-2000 The new AFT Carburetor for Harley-Davidsons was released.

Red has always been intrigued by speed and power in the motorcycle industry and his insatiable desire to continually improve on the fuel delivery to the motorcycle engine has benefited a very long list of motorcycle enthusiast and racers. The complete list of racing careers that have been enhanced would be far too long to mention, but some of the more prominent names of racers that have won championships with Red's carburetors include Kenny Roberts, Eddie Lawson, Freddie Spencer, Ricky Graham, and Doug Domokis.

With such a long history of invention successes and countless motorcycle world championships being won with Red's various carburetors, one might think that Red would be content to finish his career on top with the sale of the Qwik Silver II to the well renowned Edelbrock Corporation. But fortunately for the industry, this is not the end of the story for Red Edmonston. Red's passion for the industry has now brought him to his latest venture as part of Atomized Fuel Technologies Inc.

As the history and use of the combustion engine have changed and improved over the past decades, the majority of the mass production carburetor market for motorcycles has not. This has left many of the off-road enthusiast at risk of potentially loosing their rights for going out and enjoying the motor-sport of their liking. With the increasing world population, and the populations ever expanding concern for conserving our environment for future generations, a serious dilemma has emerged. Most Americans and Europeans prefer to live their lives with the philosophy "work hard and play hard", and this quite often includes a motor-sport of one kind or another. The majority of the time, the best performing motors for off-road toys and performance vehicles is the two-stroke combustion engine. Though this motor tends to be high in performance and enthusiast's enjoyment, it also tends to be extremely harmful to the environment because of all the harmful emissions produced by this rather simple and crude engine.

This has prompted many disagreements between the environmental groups and two-stroke vehicle manufacturers. In fact, the EPA (Environmental Protection Agency) was sued in 1998 by environmental groups for not acting quickly enough to regulate the emissions standards for recreational vehicles, especially as utilized on federal government owned land. The environmental groups won their lawsuit and the EPA is now required to provide sufficient proof of impending tightening regulations for the emissions produced by the recreational vehicle market.

The market that is about to feel the heat from these currently developing regulations is huge. There are over 22 million registered snowmobiles, watercraft, and two-stroke motorcycles in the United States and Canada. This market is currently relatively unregulated in regards to emissions standards and it appears there will be some retrofitting required of some of the current market to meet the imminent regulations.

In 1998, Red Edmonston saw this impending regulation as a threat to the industry he has lived his life so passionately to advance. So, being the eternal optimist and with his vast knowledge and experience in fuel delivery systems, he set out to develop yet another carburetor. This latest carburetor has one similar objective, more horsepower and torque than the originally equipped carburetors, but a new objective of also significantly reducing the harmful emissions from both two-stroke and four-stroke engines. Red and his son, Michael Edmonston (Michael also has a long list of motorcycle enthusiast accomplishments that include being the winning crew-chief of the 1989 Daytona super bike race), moved back into the Apple Valley building that had successfully housed the Qwik Silver manufacturing plant and began the research and development for the new HVV (high velocity venturi) carburetor.

After nearly a year of research and development, testing, changing and retesting, Red and Mike were finally ready to take their first two-stroke vehicle down to the CEE testing facility (the only California Air Resource Board – CARB approved testing facility) to have certified outside testing accomplished for their carburetors. This first test vehicle was a 1997 Honda CR250R racing motorcycle, which is an extremely popular and powerful off-road motorcycle. The results were very impressive and exceeded their expectations; with the AFT carburetor alone they were able to see a 50% decrease in harmful emissions and with the AFT carburetor and specially designed exhaust with a catalytic converter they saw harmful emissions reduced by over 85%. All this testing was completed by an independent testing agency and with the most stringent testing procedures. Along with this significant reduction in emission, the new AFT carburetor increased useable horsepower and torque by nearly 10% over the original stock carburetor.

Since accomplishing this first testing with the 1997 Honda CR250R, Red and Mike have also tested a 2000 Polaris 550RMK snowmobile and seen similar results as the first motorcycle tests. Now AFT is continuing application testing for other two-stroke vehicles and larger four-stroke cruiser motorcycles in its own Apple Valley dyno-room.

There are currently four patents or patents pending in relation to the new AFT carburetor. The two most significant new patents pending are the new oblong venturi shape that increases the velocity by the fuel needle and thus atomizes the fuel for a cleaner and more efficient burn, and the float bowl pressurization circuits that allow the carburetor to be completely altitude compensating for consistent low emission and enhanced performance at all altitudes without regard to the altitude of the motor during tuning. For more information on the simplistic, yet technically superior features of this new AFT carburetor, please read the "Technical Document" for this particular carburetor.

Since beginning this latest venture, AFT has established alliances with other companies that are attempting to help the industry via differing avenues. AFT currently holds a contract with Extengine that is working with a group of executives in China to help reduce emissions in their small two-wheel scooter/motorcycle market. China currently produces approximately 10 million of these scooter motors every year and is desperate to reduce emissions to an acceptable health level. AFT's contract is to produce a small version of the current carburetor and meet European emission standards with their small scooters. Once accomplished, the Chinese group will be licensed to manufacture the carburetors for their scooters.

JT Granatelli Lubricants, Inc. is another company alliance entered into by AFT in the pursuit of preserving the two-stroke recreational vehicle industry. JT Granatelli Lubricants, Inc. is also very interested in helping the two-stroke and four-stroke market with a product that is both performance enhancing and emissions reducing. AFT has been helping the Granatelli company by utilizing newly developed two-stoke oil fuel mixtures in the AFT dyno room. The results have shown increased motor performance with the 1997 Honda CR250R when utilizing the Granatelli oil mixture with the fuel because of increased lubricity and lower emissions created by the Granatelli oil mixed with the fuel. AFT has also utilized the flow-bench to test Granatelli catalytic converters, which will likely be required for two-stroke motors in the future to meet ever restrictive emissions standards.

AFT has now tested their carburetor and exhaust system with the EPA in Ann Arbor, Michigan and is slowly getting the word out in the industry that having a two-stoke vehicle with acceptable emissions is within our grasp. Manufacturers have not been extremely receptive to having a small company such as AFT produce a product that improves performance and emissions over their own manufactured carburetors, but AFT will continue to work at educating the industry. The recreational vehicle industry is very large and there has yet to be any product that has come from the large manufacturers, two-stroke or four-stroke, that has come close to meeting both the performance and emissions reduction that Red has accomplished with the new AFT carburetor.

All the personnel at AFT strive to help the recreational industry, environment, and ultimately the recreational enthusiast enjoy the sport of their choice. With a little effort and American ingenuity, we can all enjoy "playing hard" and still save our environment for future generations!

AFT Off-Road Carburetor Technical Document

Atomized Fuel Technologies, Inc. has developed and is currently manufacturing carburetors for off-road motorcycles, ATVs, and snowmobiles. These carburetors have been proven to increase horsepower, torque, and fuel economy, while decreasing harmful CO and Hydrocarbon emissions. This document is provided to explain the technical design and functional aspects of the AFT carburetors.

- The design team of the "new" AFT carburetors have been designing and manufacturing carburetors for over 37 years and have incorporated many of the aspects of prior models into this newly enhanced, yet simplified carburetor. Some of these features are:
  - **Dual round floats** that ride on individual guide rods. This float system has been proven to be superior to others because the floats are round and less susceptible to angle changes caused by vehicles being driven up or down hills or around inclined banks.
  - **Large capacity float bowl** for increased capacity at higher throttle positions. The larger float bowl also helps alleviate susceptibility to vehicles traveling with significant angle changes based on topology.
  - **Dual Blade flat-slide design** for reliability and better throttle response and velocity by the needle where the signal is needed.
  - **Single Circuit Metering Rod (needle)** makes this carburetor extremely easy to tune. Because there are NOT any jets in this carburetor and the adjustments are made solely via the **patented** clicker mechanism that is accessed from the top of the carburetor. The metering rod, or needle, is raised or lowered in the venturi to provide a leaner or richer fuel to air ratio for the bottom third of the throttle position (there are 50 positions in this adjustment, which makes the tuning very precise). To adjust for a leaner or richer mixture for the top two-thirds of throttle position the metering rod is easily removed from the top of the carburetor and replaced with a different needle. There are 21 different needle grinds and increasing or decreasing the size of the metering rod/needle will either provide a leaner or richer mixture (4 sizes lower or higher is the equivalent of a single size jet change so this also allows for very precise adjustments).
  - **Unique high velocity venturi (HVV) shape** increases the air velocity by the needle, which in turn creates more vacuum around the needle for increased response, torque and horsepower at low throttle positions. This feature also eliminates the need for an accelerator pump and gives more power throughout the power-band and increases power all the way through red-line RPMs. **Patent Pending on this venturi shape design.*
  - **Altitude compensating pressurization circuit** is accomplished by the unique plenum at the front of the carburetor venturi mouth. Inside this plenum are two air circuits that internally pressurize the float bowl with

the exact same atmospheric pressure that is passing by the metering rod/needle. This pressurization plenum was created to allow the pressurization of the float bowl without creating the undesirable reverse pressurization that can occur at high throttle position by installing a hole or tube for the pressurization circuit directly in the mouth of the intake venturi (the air flowing through the venturi and past a tube or hole that is directly in the venturi will actually draw air and possibly fuel out of the float bowl at high throttle positions because of the same venturi effect that is caused around the metering rod/needle). Because of the carburetors unique single circuit fuel system and the lack of fuel jets, this feature allows the carburetor to automatically compensate for altitude changes. **Patent Pending on this float bowl pressurization design.*

  - **Double tube enrichment and high idle circuit**. By pulling out the choke, the internal circuit for immediate enrichment and delayed high idle is engaged. This circuit includes a double walled tube with jet-sized holes in the bottom and in the side near the top of the float bowl. While the carburetor is not in use, both the inner and outer chamber of this tube is gravity filled with fuel. Once the vehicle is started, with the choke cable pulled, the fuel in the inner and outer tubes will be channeled into the carburetor throat behind the slide. The initial fuel from the outside tube will serve as an enrichment method for starting purposes. Once the fuel in the outer tube has diminished, the fuel will continue to be delivered only through the jet-sized whole in the bottom of the tube. This fuel will be mixed with air that is now being delivered through the hole in the upper part of the outer tube, which being delivered behind the slide will provide for a high idle until the choke cable is pushed back in and the circuit is closed.
- AFT has incorporated the best of the carburetor designs over the past 37 years of carburetor design experience of Bill "Red" and Mike Edmonston while reducing the amount of actual parts and complexities of the carburetor. This carburetor is very easy to install and tune, as well as being attractive to the eye.

AFT has created a performance enhancing carburetor (generally an eight to fifteen percent increase in horsepower and torque), as well as keeping an eye toward atomizing the fuel to create a powerful and clean burn. This carburetor has been tested with the California Air Recourse Board (CARB) testing center, CEE, as well as with the EPA in Anna Arbor, Michigan and has demonstrated a 50-55% decrease in harmful emissions on a Honda CR250R motorcycle and Polaris 550RMK Snowmobile by solely changing out the carburetor. With a specially modified exhaust pipe (a two-stage catalytic converter installed), the emissions were reduced by 80-90%, while still maintaining an increase in horsepower and torque of approximately eight percent.

AFT is continuing to run application testing as well as emissions testing in our own dyno-room, equipped with a Superflow SF600 flow-bench and SF240 Cycledyn EDI-current dyno, and look forward to providing increased performance and emissions reduction for the ever-expanding two-stroke and four-stroke recreational vehicle market.

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California Environmental Engineering
ENVIRONMENTAL TESTING LABORATORY
3231 S. STANDARD AVE. SANTA ANA, CA 92705
(714) 545-9822 FAX (714) 545-7667

3/22/00

Advanced Fuel Technologies, Inc.
13465 Nomwaket Rd.
Apple Valley, Ca. 92308

Re: Testing of the Polaris 550 snowmobile engine.

To: Mr. Edmonston,

C.E.E. has completed testing of the Polaris 550-snowmobile engine. The tests were conducted to simulate how the snowmobiles are used in Yellowstone National Park. The test was broken into three modes (idle, 1/3 throttle, 2/3 throttle). Mode 1 was at normal idle. Mode 2 was at 1/3 throttle to simulate 45 MPH of operation. Mode 3 was at 2/3 throttle, this was for engineering information. Each mode was run according to good engineering practices. When trying to simulate real world operation we often run into obstacles that we must over come, which we did. This was a very interesting test sequence, which was very close to the C.A.R.B. small engine program we are currently working on. The baseline test was with the engine in stock configuration with three modes of operation being run. The engine was then tested with AFT technologies installed on the engine with the same three modes of operation being repeated. The results are significant to say the least (see test summary). Contrary to popular belief two cycle engines can be made to pollute less with the correct technology C.E.E. looks forward to continuing with you on this important project.

Sincerely,

Larry Swiencki

Larry Swiencki
Manager

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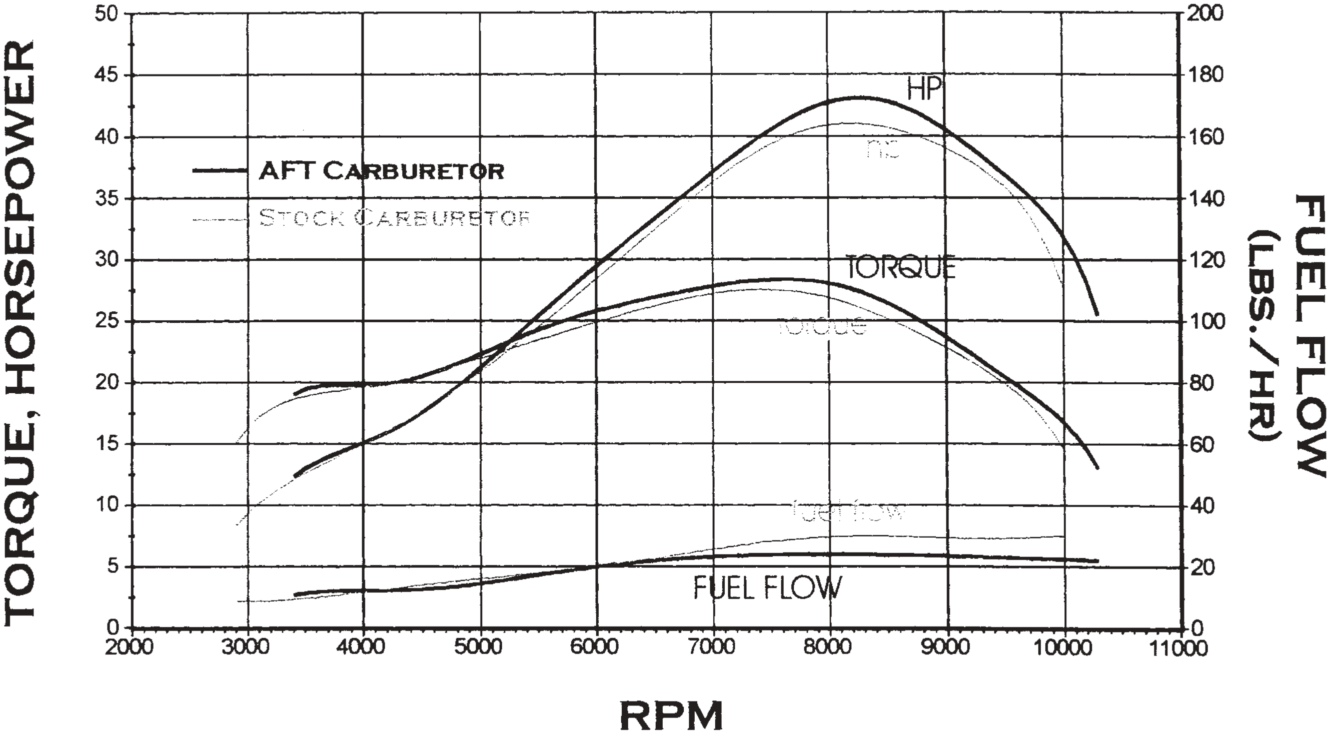
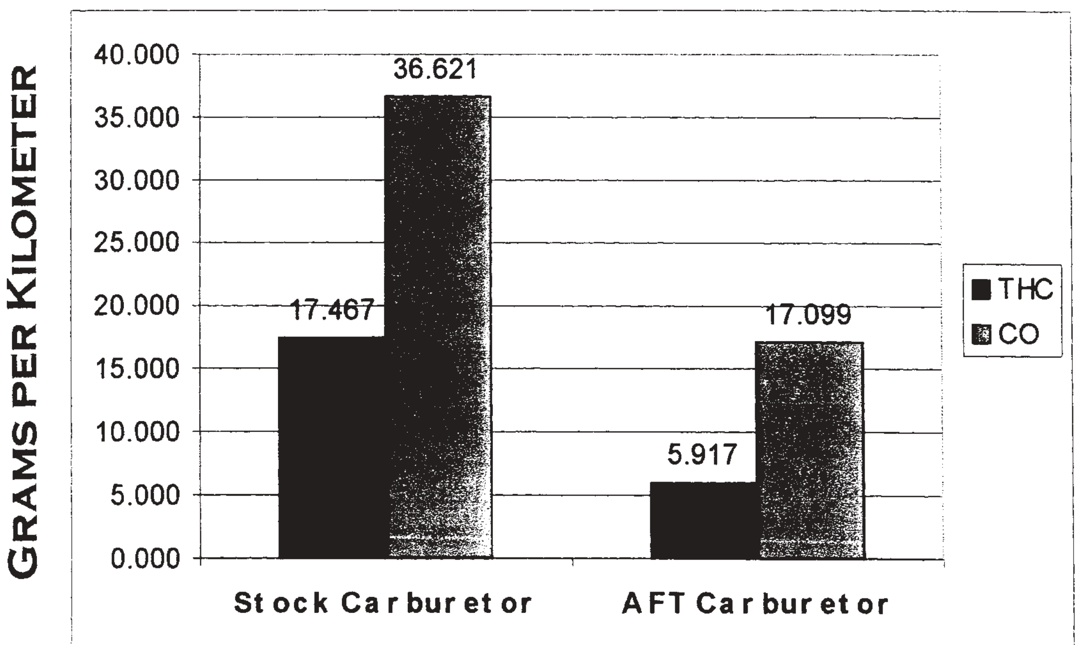
Test Result Summary

Baseline			With Cat and Carbs			% Diff	Total % Change	
Mode1	Hc	1005.7	Mode1	Hc	7.79	99.22542	72.49134	Hc Reduced
	Co	861.3		Co	28.65	96.67363	82.06625	Co Reduced
	Nox	4.1		Nox	5.49	-33.9024	-6.95689	Nox Increased
Mode 2	Hc	1540.3	Mode 2	Hc	374.89	75.66123		
	Co	2701.4		Co	668.97	75.23617		
	Nox	11.5		Nox	7.84	31.82609		
Mode 3	Hc	921.4	Mode 3	Hc	529	42.58737		
	Co	5797.7		Co	1490.65	74.28894		
	Nox	56.4		Nox	67	-18.7943		

HONDA CR250R 1997

AFT CARBURETOR VS STOCK CARBURETOR





California Environmental Engineering
3231 S. Standard Ave. Santa Ana California

TEST NUMBER	V5014216	DATE	08-26-1998	RANGE	AUTO
VEHICLE REF	RED-2	A.C.	NO	FUEL TYPE	INDOLENE
V.I.N.	JH2ME0306VM906675	ENGINE FAM.		DENSITY	16.33
OPERATOR	D.OGDEN	EVAP.FAM.		SPECIF. CO2	13.4
DRIVER	A.HERRERA			Gr.C/gal.	2421
MAKE	HONDA	TEST TYPE	E78AH4___.MCH	FUEL Fract.	.8643
MODEL	CR250R	SHIFT FILE	5SPD____.M_H	SP. GRAVITY	.7415
YEAR	1997	INERTIA WGT	3250	N.H.V.	18467
TANK CAP	2.0	ACTUAL HP	6.5	WT FACTOR	.43
ODOMETER		INDIC. HP	4.7	WT FACTOR	1
TRANS.	M-5	HP Spd/Sec	ARB 2 / 1	WT FACTOR	.57
REMARKS	HC BACKGROUND PPM=9.0				
REMARKS					
REMARKS					
START TIME	14:31:34	END TIME	15:12:42	FINAL ODO.	10

#	EVENT	MILES	Km	TIME	TIME trace		HOLD	TIME trace		ERROR	GrCtrl
1	CRANK	0.000	0.000	0.8	20.0	for	1.2	729.7	for	-27.5	795
2	phase 1	3.567	5.734	506.2	731.4	for	24.5	0.0	for	0.0	787
3	phase 2	3.823	6.145	888.5	0.0	for	0.0	0.0	for	0.0	1831
4	eng off	0.000	0.000	0.7	0.0	for	0.0	0.0	for	0.0	1835
5	phase 2	0.000	0.000	5.0	0.0	for	0.0	0.0	for	0.0	1827
6	soak+bl	0.000	0.000	15.0	0.0	for	0.0	0.0	for	0.0	263
7	soak	0.000	0.000	525.0	0.0	for	0.0	0.0	for	0.0	2
8	ready	0.000	0.000	2.3	0.0	for	0.0	0.0	for	0.0	3
9	crank 3	0.000	0.000	0.3	0.0	for	0.0	0.0	for	0.0	835
10	phase 3	3.560	5.722	505.0	0.0	for	0.0	0.0	for	0.0	835
11	delay15	0.000	0.000	15.0	0.0	for	0.0	0.0	for	0.0	3
12	bags	0.000	0.000	1.0	0.0	for	0.0	0.0	for	0.0	5
13	END	0.000	0.000	1.0	0.0	for	0.0	0.0	for	0.0	1
14	END	0.000	0.000	1.0	0.0	for	0.0	0.0	for	0.0	1
15	END	0.000	0.000	1.0	0.0	for	0.0	0.0	for	0.0	1

TEST COMPLETED 2467.0 SECONDS DVT= 32.0 A= 0.0000 B= 0.0000 HP@50= 0.0

PHASE 1	THC	CO	NOx	CO2	NMHC				
SAMPLE	2489.5	2776.3	0.49	0.234	34.7	Tdry=	80.3	Tdp =	63.4
AMBIENT	87.2	63.0	0.26	0.045	1.7	BARO.=	755.20	SEC =	507.0
GRAMS	107.730	245.481	0.039	272.19	106.250	NoxKf=	1.064	VOLc=	2740.5
GMS/MI	30.202	68.820	0.011	76.31	29.787	M.P.G.	31.66	DF =	17.618
g/Mwgt	6.268	14.283	0.002	15.84	6.182	MPGnhv	48.11	MI =	3.567
						R-H =	56.40	KM =	5.733

PHASE 2	THC	CO	NOx	CO2	NMHC				
SAMPLE	1284.0	1171.5	0.28	0.142	20.6	Tdry=	82.1	Tdp =	63.5
AMBIENT	38.6	16.8	0.24	0.043	1.2	BARO.=	755.00	SEC =	894.2
GRAMS	98.371	184.057	0.013	251.18	96.830	NoxKf=	1.066	VOLc=	4832.6
GMS/MI	25.731	48.145	0.003	65.70	25.328	M.P.G.	39.80	DF =	34.576
g/Mwgt	12.866	24.072	0.002	32.85	12.664	MPGnhv	62.78	MI =	3.823
						R-H =	53.40	KM =	6.145

PHASE 3	THC	CO	NOx	CO2	NMHC				
SAMPLE	2544.2	2893.9	0.41	0.218	40.1	Tdry=	82.1	Tdp =	63.5
AMBIENT	81.4	67.5	0.25	0.045	1.7	BARO.=	755.10	SEC =	505.3
GRAMS	109.944	254.614	0.027	248.38	108.230	NoxKf=	1.066	VOLc=	2728.6
GMS/MI	30.883	71.521	0.008	69.77	30.401	M.P.G.	31.68	DF =	17.590
g/Mwgt	8.488	19.657	0.002	19.18	8.355	MPGnhv	48.72	MI =	3.560
						R-H =	53.40	KM =	5.722

****

WEIGHTED	THC	CO	NOx	CO2	NMHC	FUEL ECONOMY			
GRAMS/MI	28.075	58.861	0.006	69.02	27.648	M.P.G.	35.42	NHVmpg	54.941
GRAMS/KM	17.467	36.621	0.004	42.94	17.201	L/100k	6.64	NHVkpl	23.360

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Trap Vol. S 1 = 528.2906 A= 0.0000
Trap Vol. S 2 = 931.5882 A= 0.0000
Trap Vol. S 3 = 525.9967 A= 0.0000

California Environmental Engineering
3231 S. Standard Ave. Santa Ana California

TEST NUMBER	V5014282	DATE	09-03-1998	RANGE	AUTO
VEHICLE REF	RED-2	A.C.	NO	FUEL TYPE	INDOLENE
V.I.N.	JH2ME0306VM906675	ENGINE FAM.		DENSITY	16.33
OPERATOR	D.OGDEN	EVAP.FAM.		SPECIF. CO2	13.4
DRIVER	A.HERRERA			Gr.C/gal.	2421
MAKE	HONDA	TEST TYPE	EPA78A .LA4	FUEL Fract.	.8643
MODEL	CR250R	SHIFT FILE	SHIFT .L_4	SP. GRAVITY	.7415
YEAR	1997	INERTIA WGT	3250	N.H.V.	18467
TANK CAP	2.0	ACTUAL HP	6.5	WT FACTOR	.43
ODOMETER		INDIC. HP	4.7	WT FACTOR	1
TRANS.	M-5	HP Spd/Sec	ARB 2 / 1	WT FACTOR	.57
REMARKS	HC BACKGROUND PPM=6.0				
REMARKS	W/NEW CARB				
REMARKS					
START TIME	14:03:36	END TIME	14:44:38	FINAL ODO.	11

#	EVENT	MILES	Km	TIME	TIME trace	HOLD	TIME trace	ERROR	GrCtrl
1	Ready	0.000	0.000	0.2	0.0 for	0.0	0.0 for	0.0	1
2	Delay 10	0.000	0.000	10.0	0.0 for	0.0	0.0 for	0.0	1
3	Ready	0.000	0.000	0.7	0.0 for	0.0	0.0 for	0.0	281
4	CRANK	0.000	0.000	6.4	0.0 for	0.0	0.0 for	0.0	795
5	phase 1	3.579	5.753	505.0	0.0 for	0.0	0.0 for	0.0	787
6	phase 2	3.842	6.175	864.0	0.0 for	0.0	0.0 for	0.0	1831
7	eng off	0.000	0.000	3.9	0.0 for	0.0	0.0 for	0.0	1835
8	phase 2	0.000	0.000	5.0	0.0 for	0.0	0.0 for	0.0	1827
9	soak+bl	0.001	0.001	15.0	0.0 for	0.0	0.0 for	0.0	775
10	soak	0.003	0.006	525.0	0.0 for	0.0	0.0 for	0.0	2
11	ready	0.000	0.000	5.6	0.0 for	0.0	0.0 for	0.0	3
12	crank 3	0.000	0.000	0.7	0.0 for	0.0	0.0 for	0.0	835
13	phase 3	3.578	5.750	505.0	0.0 for	0.0	0.0 for	0.0	835
14	delay15	0.000	0.000	15.0	0.0 for	0.0	0.0 for	0.0	3
15	bags	0.000	0.000	1.0	0.0 for	0.0	0.0 for	0.0	7

TEST COMPLETED 2445.3 SECONDS DVT= 1.7 A= 0.0000 B= 0.0000 HP@50= 0.0

PHASE 1	THC	CO	NOx	CO2	NMHC				
SAMPLE	746.3	1094.5	0.37	0.263	5.3	Tdry=	85.0	Tdp =	69.1
AMBIENT	22.7	0.7	0.09	0.048	.9	BARO.=	748.80	SEC =	512.1
GRAMS	32.566	99.286	0.050	309.19	32.365	NoxKf=	1.186	VOLc=	2753.1
GMS/MI	9.099	27.741	0.014	86.39	9.043	M.P.G.	55.85	DF =	29.972
G/Mwgt	1.887	5.753	0.003	17.92	1.875	MPGnhv	68.27	MI =	3.579
						R-H =	59.10	KM =	5.753

PHASE 2	THC	CO	NOx	CO2	NMHC				
SAMPLE	500.5	588.1	0.11	0.156	7.6	Tdry=	85.6	Tdp =	69.5
AMBIENT	15.0	1.2	0.09	0.046	.9	BARO.=	748.70	SEC =	872.9
GRAMS	37.211	90.767	0.007	269.74	36.695	NoxKf=	1.196	VOLc=	4690.6
GMS/MI	9.685	23.625	0.002	70.21	9.551	M.P.G.	64.26	DF =	50.593
G/Mwgt	4.843	11.812	0.001	35.10	4.775	MPGnhv	82.68	MI =	3.842
						R-H =	58.80	KM =	6.175

PHASE 3	THC	CO	NOx	CO2	NMHC				
SAMPLE	791.9	1382.5	0.31	0.245	9.0	Tdry=	85.4	Tdp =	69.8
AMBIENT	27.2	2.2	0.08	0.047	.9	BARO.=	748.60	SEC =	505.7
GRAMS	33.968	123.644	0.041	281.20	33.606	NoxKf=	1.204	VOLc=	2716.8
GMS/MI	9.494	34.557	0.012	78.59	9.392	M.P.G.	54.42	DF =	28.977
G/Mwgt	2.609	9.498	0.003	21.60	2.581	MPGnhv	66.78	MI =	3.578
						R-H =	59.70	KM =	5.751

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WEIGHTED	THC	CO	NOx	CO2	NMHC	FUEL ECONOMY			
GRAMS/MI	9.511	27.483	0.007	75.87	9.402	M.P.G.	59.45	NHVmpg	74.537
GRAMS/KM	5.917	17.099	0.004	47.20	5.849	L/100k	3.96	NHVkpl	31.691

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Trap Vol. S 1 = 530.7196 A= 0.0000
Trap Vol. S 2 = 904.2147 A= 0.0000
Trap Vol. S 3 = 523.7220 A= 0.0000

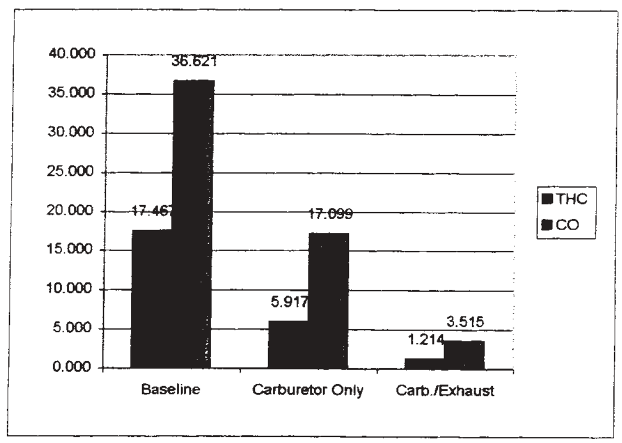
1997 HONDA CR250R

TEST # BASELINE		THC	CO	NOX	CO2	NMHC		THC	CO	NOX	CO2	NMHC
								C.A.R.B. STD.				
	Sample 1	2489.5	2776.3	0.49	0.234	34.7						
	Sample 2	1284.0	1171.5	0.28	0.142	20.6		CURRENT 2&4-STROKE OFF-ROAD				
	Sample 3	2544.2	2893.9	0.41	0.218	40.1						
	Grams/MI	28.075	58.861	0.006	69.02	27.648						
	Grams/KM	17.467	36.621	0.004	42.94	17.201	Grams/KM	1.2	15	-	-	-
Carburetor Only								REDUCED PERCENTAGE				
	Sample 1	746.3	1094.5	0.37	0.263	5.3	Sample 1	70%	61%	24%	-12%	85%
	Sample 2	500.5	588.1	0.11	0.156	7.6	Sample 2	61%	50%	61%	-10%	63%
	Sample 3	791.9	1382.5	0.31	0.245	9.0	Sample 3	69%	52%	24%	-12%	78%
	Grams/MI	9.511	27.483	0.007	75.870	9.402	Grams/MI	66%	53%	-17%	-10%	66%
	Grams/KM	5.917	17.099	0.004	47.200	5.849	Grams/KM	66%	53%	0%	-10%	66%
Carburetor/ Exhaust								REDUCED PERCENTAGE				
	Sample 1	361.3	443.6	0.56	0.274	27.9	Sample 1	85%	84%	-14%	-17%	20%
	Sample 2	43.3	14.0	0.36	0.205	3.1	Sample 2	97%	99%	-29%	-44%	85%
	Sample 3	184.9	429.9	0.42	0.305	0.0	Sample 3	93%	85%	-2%	-40%	100%
	Grams/MI	1.951	5.650	0.013	103.05	1.948	Grams/MI	93%	90%	-117%	-49%	93%
	Grams/KM	1.214	3.515	0.008	64.12	1.212	Grams/KM	93%	90%	-100%	-49%	93%

TEST SUMMARY

	THC	CO	NOX	CO2	NMHC
Baseline	17.467	36.621	0.004	42.94	17.201
arburetor Only	5.917	17.099	0.004	47.200	5.849
Carb./Exhaust	1.214	3.515	0.008	64.12	1.212

THC=HYDROCARBON
CO=CARBON MONOXIDE
NOX=NITROGEN OXIDES
CO2=CARBON DIOXIDE



California Environmental Engineering
3231 S. Standard Ave. Santa Ana California

TEST NUMBER	V5014834	DATE	11-04-1998	RANGE	AUTO
VEHICLE REF	RED-2	A.C.	NO	FUEL TYPE	INDOLENE
V.I.N.	JH2ME0306VM906675	ENGINE FAM.		DENSITY	16.33
OPERATOR	L.SWIENCKI	EVAP.FAM.		SPECIF. CO2	13.4
DRIVER	D.OGDEN			Gr.C/gal.	2421
MAKE	HONDA	TEST TYPE	EPA78A .LA4	FUEL Fract.	.8643
MODEL	CR250R	SHIFT FILE	SHIFT .L_4	SP. GRAVITY	.7415
YEAR	1997	INERTIA WGT	3250	N.H.V.	18467
TANK CAP	2.0	ACTUAL HP	6.5	WT FACTOR	.43
ODOMETER		INDIC. HP	4.7	WT FACTOR	1
TRANS.	M-5	HP Spd/Sec	ARB 2 / 1	WT FACTOR	.57
REMARKS	WITH CARB & CAT				
REMARKS					
REMARKS					
START TIME	13:24:39	END TIME	14:05:51	FINAL ODO.	11

#	EVENT	MILES	Km	TIME	TIME trace HOLD	TIME trace ERROR	GrCtrl
1	Ready	0.000	0.000	0.1	0.0 for 0.0	0.0 for 0.0	1
2	Delay 10	0.000	0.000	10.0	0.0 for 0.0	0.0 for 0.0	1
3	Ready	0.000	0.000	0.4	0.0 for 0.0	0.0 for 0.0	281
4	CRANK	0.000	0.000	5.2	0.0 for 0.0	0.0 for 0.0	795
5	phase 1	3.583	5.759	505.0	0.0 for 0.0	0.0 for 0.0	787
6	phase 2	3.851	6.189	864.0	0.0 for 0.0	0.0 for 0.0	1831
7	eng off	0.000	0.000	2.0	0.0 for 0.0	0.0 for 0.0	1835
8	phase 2	0.000	0.000	5.0	0.0 for 0.0	0.0 for 0.0	1827
9	soak+bl	0.000	0.000	15.0	0.0 for 0.0	0.0 for 0.0	775
10	soak	0.000	0.000	525.0	0.0 for 0.0	0.0 for 0.0	2
11	ready	0.000	0.000	18.3	0.0 for 0.0	0.0 for 0.0	3
12	crank 3	0.000	0.000	0.5	0.0 for 0.0	0.0 for 0.0	835
13	phase 3	3.580	5.755	505.0	0.0 for 0.0	0.0 for 0.0	835
14	delay15	0.000	0.000	15.0	0.0 for 0.0	0.0 for 0.0	3
15	bags	0.000	0.000	1.0	0.0 for 0.0	0.0 for 0.0	7

TEST COMPLETED 2455.8 SECONDS DVT= 0.2 A= 0.0000 B= 0.0000 HP@50= 0.0

PHASE 1	THC	CO	NOx	CO2	NMHC				
SAMPLE	361.3	443.6	0.56	0.274	27.9	Tdry=	78.0	Tdp =	56.1
AMBIENT	7.4	0.0	0.15	0.042	27.9	BARO.=	756.90	SEC =	510.6
GRAMS	16.165	40.887	0.060	337.90	16.132	NoxKf=	0.965	VOLc=	2795.6
GMS/MI	4.512	11.411	0.017	94.31	4.502	M.P.G.	70.09	DF =	37.801
G/Mwgt	0.935	2.365	0.003	19.55	.933	MPGnhv	79.07	MI =	3.583
						R-H =	46.90	KM =	5.759

PHASE 2	THC	CO	NOx	CO2	NMHC				
SAMPLE	43.3	14.0	0.36	0.205	3.1	Tdry=	79.3	Tdp =	56.3
AMBIENT	5.5	0.0	0.20	0.042	3.1	BARO.=	756.50	SEC =	871.0
GRAMS	2.950	2.201	0.041	404.67	2.947	NoxKf=	0.967	VOLc=	4768.8
GMS/MI	0.766	0.572	0.011	105.08	.765	M.P.G.	81.81	DF =	63.588
G/Mwgt	0.383	0.286	0.005	52.54	.382	MPGnhv	83.73	MI =	3.851
						R-H =	45.30	KM =	6.190

PHASE 3	THC	CO	NOx	CO2	NMHC				
SAMPLE	184.9	429.9	0.42	0.305	.0	Tdry=	78.3	Tdp =	54.7
AMBIENT	6.4	2.7	0.05	0.042	.0	BARO.=	756.50	SEC =	505.5
GRAMS	8.071	38.968	0.053	378.86	8.071	NoxKf=	0.950	VOLc=	2766.2
GMS/MI	2.255	10.885	0.015	105.83	2.254	M.P.G.	68.18	DF =	36.564
G/Mwgt	0.619	2.989	0.004	29.06	.619	MPGnhv	72.19	MI =	3.580
						R-H =	44.20	KM =	5.754

****

WEIGHTED	THC	CO	NOx	CO2	NMHC	FUEL ECONOMY			
GRAMS/MI	1.951	5.650	0.013	103.05	1.948	M.P.G.	75.08	NHVmpg	79.282
GRAMS/KM	1.214	3.515	0.008	64.12	1.212	L/100k	3.13	NHVkpl	33.709

****

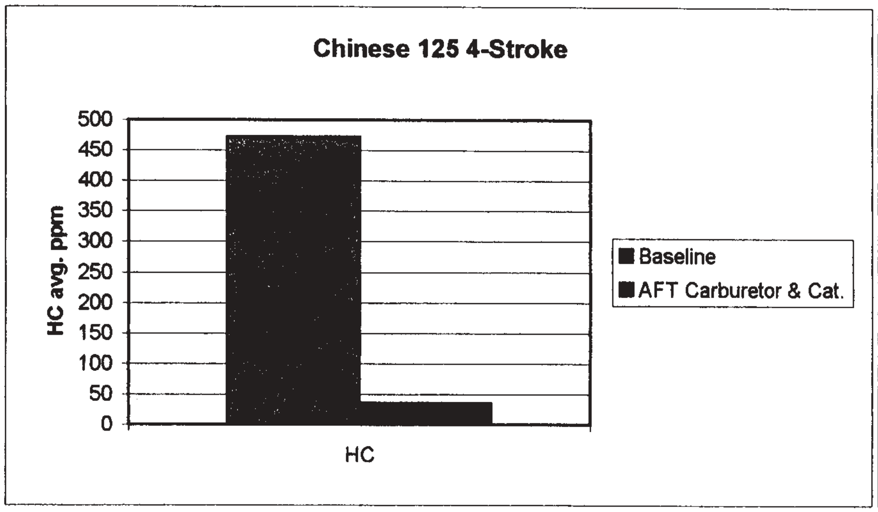
Trap Vol. S 1 = 534.8179 A= 0.0000
Trap Vol. S 2 = 912.3048 A= 0.0000
Trap Vol. S 3 = 529.1934 A= 0.0000

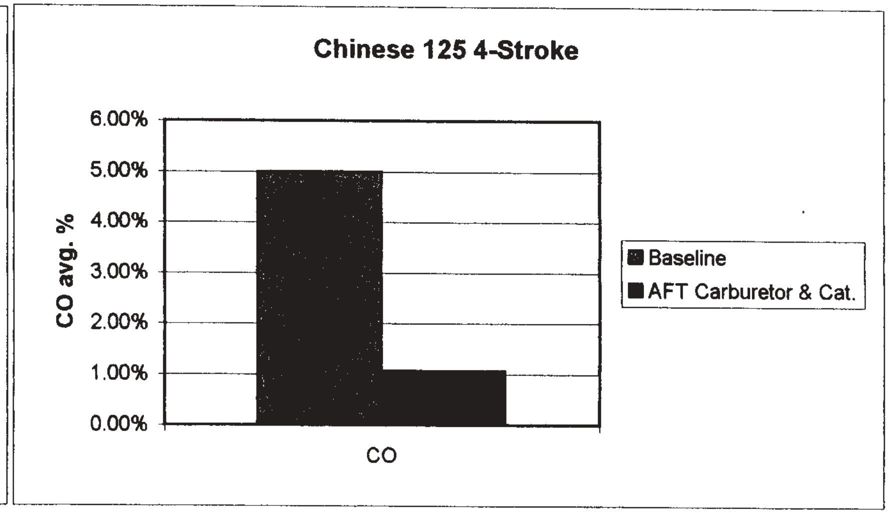
Atomized Fuel Technologies, Inc. Research & Development

Project: Chinese 125cc 4-Stroke
Test: European ECE15

Results:

	HC avg. ppm	CO avg. %
Baseline	472.5	5.00%
AFT Carburetor & Cat.	34.7	1.06%
Reduction	437.8	3.94%
% of Reduction	92.7%	78.8%





2000 POLARIS
550 RMK

Note: Tests were conducted on a motor pulled from use in Yellowstone Park with apprximately 5500 miles of usage.

BASELINE

		HC		CO		NOX		CO2	Fuel Flow
		ppm	g/h	%	g/h	ppm	g/h	%	lb/hr
Idle	Mode 1	57268.21	1005.7074	2.55	861.3121	77.78	4.1543	4.14	4.68
1/3 Throttle (45mph)	Mode 2	51621.99	1540.2933	4.85	2701.3676	125.63	11.5141	6.35	10.20
	Avg.	*54445.10*	*1273.00*	*3.70*	*1781.34*	*101.71*	*7.83*	*5.25*	*7.44*
2/3 Throttle	Mode 3	15041.47	921.3749	5.13	5797.6765	293.62	56.3591	7.55	17.66
	Avg. (all 3)	*41310.56*	*1155.7919*	*4.18*	*3120.1187*	*165.68*	*24.01*	*6.01*	*10.85*

Note: Modes 1 & 2 simulate conditions in Yellowstone Park. Mode 3 is for engineering practices.

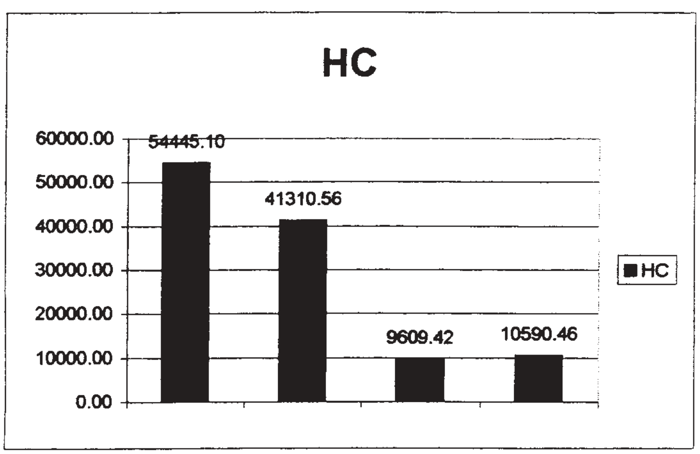
AFT CARB & EXHAUST

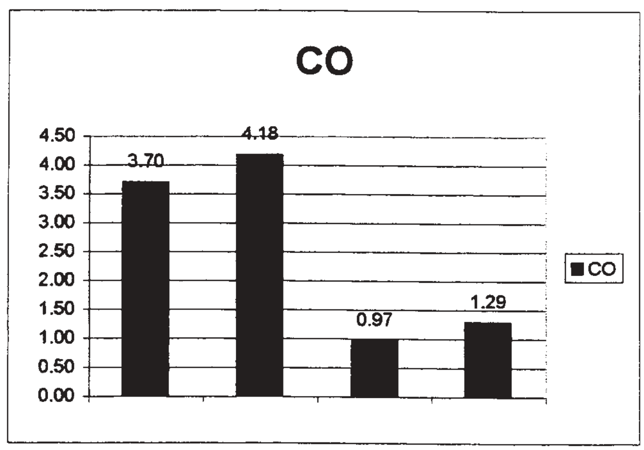
		HC		CO		NOX		CO2	Fuel Flow
		ppm	g/h	%	g/h	ppm	g/h	%	lb/hr
Idle	Mode 1	586.27	7.7906	0.12	28.6531	129.33	5.4911	9.410	2.58
1/3 Throttle (45mph)	Mode 2	18632.56	374.8909	1.81	668.9735	121.38	7.8408	9.950	5.56
	Avg.	*9609.42*	*191.34*	*0.97*	*348.81*	*125.36*	*6.6660*	*9.680*	*4.07*
	% Decr./Incr.	-82%	-85%		-80%				-45%
2/3 Throttle	Mode 3	12552.55	529.0068	1.93	1490.6523	492.38	67.0229	9.770	11.04
	Avg. (all 3)	*10590.46*	*303.8961*	*1.29*	*729.4263*	*247.70*	*26.78*	*9.71*	*6.39*
	% Decrease	-74%	-74%		-77%				-41%

TEST SUMMARY

	HC	*CO*	NOX	CO2	*Fuel Flow*
Stock Baseline-Yellowstone Park	*54445.10*	*3.70*	101.71	5.25	*7.44*
Stock Baseline-Overall	*41310.56*	*4.18*	165.68	6.01	*10.85*
AFT Carb./Exhaust-Yellowstone Park	*9609.42*	*0.97*	125.36	9.68	*4.07*
AFT Carb./Exhaust-Overall	*10590.46*	*1.29*	247.70	9.71	*6.39*

HC=HYDROCARBON
CO=CARBON MONOXIDE
NOX=NITROGEN OXIDES
CO2=CARBON DIOXIDE





2000 POLARIS 550 RMK
STOCK BASELINE

Test Performed By:

California Environmental Engineering
3231 S. Standard Ave, Santa Ana, Ca 92705

Date : 3/22/00
Time : 12:06:06

Test Number	:	DT200023
Tech	:	B.LEE
Fuel Type	:	
Engine Type	:	POLARIS 550
Engine Number	:	
Engine Model	:	
HP	:	
Torque	:	
Max RPM	:	
Idle RPM	:	
COMMENTS	:	BASELINE STOCK CARBS AND EXHAUST

Mode 1 / Weight 100.00%

Parameter	English Units	SI Units
AirFlow rate (dry)	2.54 lb/h	1150.50 g/h
Fuel flow rate	4.68 lb/h	2122.80 g/h
Engine speed	2235.70 rpm	2235.70 rpm
Engine torque output	7.36 lb-ft	32.75 Nm
Power output	3.18 hp	2.37 kW
Air inlet Temperature	0.00 øF	-17.78 øC
Air humidity	55.50 grains/lb dry air	7928.71 mg/kg
Relative humidity	44.75 %	44.75 %
Dyno temperature	0.00 øF	-17.78 øC
Exhaust mixing chamber temp	0.00 øF	-17.78 øC
Exhaust sample line temp	349.78 øF	176.54 øC
Cell Temperature	73.96 øF	23.31 øC
Engine oil temp	0.00 øF	-17.78 øC
Engine oil pressure	2.01 psi	0.14 bar
Barometer	30.00 in. hg	762.11 mm mg.

HC	57268.21 ppm	1005.7074 g/h	1005.7074 weighted g/h
CO	2.55 %	861.3121 g/h	861.3121 weighted g/h
NOX	77.78 ppm	4.1543 g/h	4.1543 weighted g/h
CO2	4.14 %		

kH NOx humidity cor. = 0.9160483654
H2 dry to wet sub factor = 1.0556683175
K dry to wet sub factor = 0.9511990102

Mode 2 / Weight 100.00%

Parameter	English Units	SI Units

2000 POLARIS 550 RMK
STOCK BASELINE

AirFlow rate (dry)	2.54 lb/h	1150.50 g/h
Fuel flow rate	10.20 lb/h	4627.20 g/h
Engine speed	4334.77 rpm	4334.77 rpm
Engine torque output	16.12 lb-ft	71.72 Nm
Power output	13.28 hp	9.90 kW
Air inlet Temperature	0.00 øF	-17.78 øC
Air humidity	57.79 grains/lb dry air	8255.17 mg/kg
Relative humidity	40.35 %	40.35 %
Dyno temperature	0.00 øF	-17.78 øC
Exhaust mixing chamber temp	0.00 øF	-17.78 øC
Exhaust sample line temp	349.93 øF	176.63 øC
Cell Temperature	78.27 øF	25.71 øC
Engine oil temp	0.00 øF	-17.78 øC
Engine oil pressure	2.29 psi	0.16 bar
Barometer	30.00 in. hg	761.90 mm mg.

HC	51621.99 ppm	1540.2933 g/h	1540.2933 weighted g/h
CO	4.85 %	2701.3676 g/h	2701.3676 weighted g/h
NOX	125.63 ppm	11.5141 g/h	11.5141 weighted g/h
CO2	6.35 %		

kH NOx humidity cor. = 0.9251508429
H2 dry to wet sub factor = 2.1035384236
K dry to wet sub factor = 0.9237312797

Mode 3 / Weight 100.00%
==

Parameter	English Units	SI Units
AirFlow rate (dry)	2.54 lb/h	1150.50 g/h
Fuel flow rate	17.66 lb/h	8011.20 g/h
Engine speed	6719.23 rpm	6719.23 rpm
Engine torque output	25.93 lb-ft	115.35 Nm
Power output	33.03 hp	24.63 kW
Air inlet Temperature	0.00 øF	-17.78 øC
Air humidity	62.33 grains/lb dry air	8904.72 mg/kg
Relative humidity	38.14 %	38.14 %
Dyno temperature	0.00 øF	-17.78 øC
Exhaust mixing chamber temp	0.00 øF	-17.78 øC
Exhaust sample line temp	349.85 øF	176.58 øC
Cell Temperature	82.28 øF	27.93 øC
Engine oil temp	0.00 øF	-17.78 øC
Engine oil pressure	2.41 psi	0.17 bar
Barometer	29.99 in. hg	761.78 mm mg.

HC	15041.47 ppm	921.3749 g/h	921.3749 weighted g/h
CO	5.13 %	5797.6765 g/h	5797.6765 weighted g/h
NOX	293.62 ppm	56.3591 g/h	56.3591 weighted g/h
CO2	7.55 %		

kH NOx humidity cor. = 0.9438105103
H2 dry to wet sub factor = 2.1679176298
K dry to wet sub factor = 0.9127234496

2000 POLARIS 550 RMK
AFT CARBURETOR AND EXHAUST SYSTEM

Test Performed By:

California Environmental Engineering
3231 S. Standard Ave, Santa Ana, Ca 92705

Date : 3/22/00
Time : 4:40:11

Test Number	:	DT200027
Tech	:	B.LEE
Fuel Type	:	
Engine Type	:	POLARIS 550
Engine Number	:	
Engine Model	:	
HP	:	
Torque	:	
Max RPM	:	
Idle RPM	:	
COMMENTS	:	WITH CAT AND CARBS BY AFT

Mode 1 / Weight 100.00% / 1700 rpm / 0.00 torque
==

Parameter	English Units	SI Units
AirFlow rate (dry)	2.54 lb/h	1150.50 g/h
Fuel flow rate	2.58 lb/h	1171.20 g/h
Engine speed	2622.20 rpm	2622.20 rpm
Engine torque output	3.74 lb-ft	16.65 Nm
Power output	1.90 hp	1.42 kW
Air inlet Temperature	0.00 øF	-17.78 øC
Air humidity	66.67 grains/lb dry air	9523.82 mg/kg
Relative humidity	39.42 %	39.42 %
Dyno temperature	0.00 øF	-17.78 øC
Exhaust mixing chamber temp	0.00 øF	-17.78 øC
Exhaust sample line temp	349.93 øF	176.63 øC
Cell Temperature	83.30 øF	28.50 øC
Engine oil temp	0.00 øF	-17.78 øC
Engine oil pressure	2.35 psi	0.16 bar
Barometer	29.98 in. hg	761.51 mm mg.

HC	586.27 ppm	7.7906 g/h	7.7906 weighted g/h
CO	0.12 %	28.6531 g/h	28.6531 weighted g/h
NOX	129.33 ppm	5.4911 g/h	5.4911 weighted g/h
CO2	9.41 %		

kH NOx humidity cor. = 0.9623099121
H2 dry to wet sub factor = 0.0360934601
K dry to wet sub factor = 0.9193466658

Mode 2 / Weight 100.00% / 1700 rpm / 0.00 torque
==

Parameter	English Units	SI Units

2000 POLARIS 550 RMK
AFT CARBURETOR AND EXHAUST SYSTEM

AirFlow rate (dry)	4.91 lb/h	2224.91 g/h
Fuel flow rate	5.56 lb/h	2521.20 g/h
Engine speed	4564.83 rpm	4564.83 rpm
Engine torque output	16.10 lb-ft	71.64 Nm
Power output	13.90 hp	10.37 kW
Air inlet Temperature	0.00 øF	-17.78 øC
Air humidity	67.75 grains/lb dry air	9678.10 mg/kg
Relative humidity	36.96 %	36.96 %
Dyno temperature	0.00 øF	-17.78 øC
Exhaust mixing chamber temp	0.00 øF	-17.78 øC
Exhaust sample line temp	349.63 øF	176.46 øC
Cell Temperature	85.80 øF	29.89 øC
Engine oil temp	0.00 øF	-17.78 øC
Engine oil pressure	2.39 psi	0.17 bar
Barometer	29.98 in. hg	761.54 mm mg.

HC	18632.56 ppm	374.8909 g/h	374.8909 weighted g/h
CO	1.81 %	668.9735 g/h	668.9735 weighted g/h
NOX	121.38 ppm	7.8408 g/h	7.8408 weighted g/h
CO2	9.95 %		

kH NOx humidity cor. = 0.9670333300
H2 dry to wet sub factor = 0.6237210084
K dry to wet sub factor = 0.9069807153

Mode 3 / Weight 100.00% / 1700 rpm / 0.00 torque
==

Parameter	English Units	SI Units
AirFlow rate (dry)	2.54 lb/h	1150.50 g/h
Fuel flow rate	11.04 lb/h	5006.40 g/h
Engine speed	6490.10 rpm	6490.10 rpm
Engine torque output	25.19 lb-ft	112.07 Nm
Power output	33.88 hp	25.26 kW
Air inlet Temperature	0.00 øF	-17.78 øC
Air humidity	69.06 grains/lb dry air	9865.88 mg/kg
Relative humidity	38.04 %	38.04 %
Dyno temperature	0.00 øF	-17.78 øC
Exhaust mixing chamber temp	0.00 øF	-17.78 øC
Exhaust sample line temp	349.86 øF	176.59 øC
Cell Temperature	85.49 øF	29.72 øC
Engine oil temp	0.00 øF	-17.78 øC
Engine oil pressure	2.37 psi	0.16 bar
Barometer	29.98 in. hg	761.62 mm mg.

HC	12552.55 ppm	529.0068 g/h	529.0068 weighted g/h
CO	1.93 %	1490.6523 g/h	1490.6523 weighted g/h
NOX	492.38 ppm	67.0229 g/h	67.0229 weighted g/h
CO2	9.77 %		

kH NOx humidity cor. = 0.9728454970
H2 dry to wet sub factor = 0.6681605880
K dry to wet sub factor = 0.9077893235

Status and Potential of Two-Stroke Engine Technology in Montana

August 2001

Prepared by Emily Miller, Research Consultant
Under a subcontract from
The National Center for Appropriate Technology

Commissioned by the
Montana Department of Environmental Quality
Contract Manager--Howard Haines, Bioenergy Engineer

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Table of Contents

EXECUTIVE SUMMARY

This study was commissioned by the Montana Legislature under the guidance to the Department of Environmental Quality[1] to research the status of two-stroke engine technology development in Montana with a focus on identifying the best 'fit' for Montana and advanced two-stroke engines. Additional study elements include the identification of the 'players' or 'stakeholders' in Montana; the Montana market for two-stroke engines; and state-specific technical, regulatory, and/or commercial barriers to this technology, and if they exist, how can they be overcome.

Montana's strongest connection to the two-stroke engine has historically been associated with seasonal recreational uses, i.e., snowmobiling, off-highway vehicles (OHVs) including motorcycles, marine engines and personal watercraft (PWCs) or jet skis. Snowmobiling generates the greatest economic development for Montana, $44 million in nonresident expenditures in 1998[2], in large part due to the activity in and around Yellowstone National Park. Nonresident expenditures were also measured for OHVs and net economic benefits were found to be modest and possibly negative due to trail upkeep costs and low non-resident expenditures. No quantifiable measures were found for PWCs and they are the smallest recreational group of the three. There are an estimated 33,400 outboard motorboats in Montana with the vast majority assumed to be older two-stoke engines.

The use of two-stroke engines in forestry and mining was also investigated. In both applications, the use is quite modest, i.e., there were 1,983 professional 'fallers' and 'buckers' in 1998 statewide and 100 or less two-stroke engines used in today's hard rock mining operations.

---

[1] Funding for this study came through the Petroleum Violating Escrow Fund to be used for more efficient energy usage or petroleum displacements.

[2] Residents also generated an estimated $35 million in in-state expenditures. Eleven million dollars in labor income to Montanans providing goods and services to the snowmobile industry was also generated in in the 1997-98 season as estimated by the University of Montana Bureau of Business and Economic Research.

There is no research & development (R&D), or manufacturing of two-stroke engines in Montana. A few small Montana-based companies were identified that produce and sell aftermarket specialty components for ultra high performance snowmobiles and OHVs.

The Business Recruiter for the Montana Department of Commerce indicated that the state can only offer modest direct financial incentives for attracting new business and these incentives are provided to local communities which then try to develop matching funds and leverage federal programs such as HUD Community Development Block Grants and US Department of Labor in-plant training dollars. Efforts to recruit small innovative manufacturers to relocate to Montana will need to be spearheaded by local communities or innovative public/private collaborations.

More stringent Federal environmental regulations set in motion by state agencies such as Montana DEQ, are affecting virtually all applications of two-stroke engines in Montana. The results, still unfolding, will be technology substitution to four-stroke engines, and improvements in two-stroke engines such as the use of fuel injection and adjustable exhaust tuning. In 1999, the State of Montana passed the *Montana No Wake (Jet Ski) Law (HB626)* to counter growing opposition to uncontrolled use of PWCs.

The primary stakeholders include business interests (manufacturers, sales and rental), local economic development organizations (e.g., West Yellowstone and Lincoln Chambers of Commerce), advocacy groups of multiple use for public lands (e.g., the BlueRibbon Coalition) environmental groups (e.g., the Greater Yellowstone Coalition), state and federal land managers (e.g., Montana Department of Fish, Wildlife and Parks, DEQ, US Forest Service, National Park Service, and the US Bureau of Land Management), residents of recreational areas (e.g., the Flathead Lakers), and local and national media.

The stakeholders are, not surprisingly, often at opposition. PWC and snowmobile trade groups are litigating recent court decisions that prohibit the use of their products on certain public lands, most notably, snowmobiles in Yellowstone National Park. In a nationwide poll of 1, 003 likely voters conducted in May 2001,[1] 70 percent of the respondents supported a continued phase out of snowmobiles in Yellowstone National Park even with cleaner and quieter models. This recent poll is being widely published in the wake of the June 24th, 2001 *New York Times* article[2] that the Bush administration may be on the verge of reversing the National Park Service's recommended ban on personal snowmobiles in Yellowstone National Park.

There is also growing local opposition, such as the Flathead Lakers Association and local residents, towards the perceived danger and environmental damage caused by PWCs. In both instances, it is likely that there will be greater limits on access to public lands and that the new models of these recreation vehicles will be quieter and less polluting than the old models. Some Montanans fear that older, more polluting models will be "dumped" in Montana where state and local regulations are less stringent than places such as Lake Tahoe in northern California.

In terms of Montana economic development, the greatest need and opportunity is to preserve and build on the existing tourism base ensuring safety and access to public lands using improved engine technology. It is possible that this emotionally charged public land access issue of motorized recreational vehicles will promote advanced two-stroke engine technology for responsible use on public lands.

I. PROJECT INTRODUCTION

The Montana Department of Environmental Quality (DEQ) contracted with the National Center for Appropriate Technology (NCAT) headquartered in Butte, Montana, with the overall task of researching and promoting *advanced* two-stroke engine technologies. The initial funding for this study came from a legislative appropriation from the State of Montana whose main interest is in wise use of energy resources.

The project has three distinct components.

1. In April 2001 Chrysalis Technology Group, Ltd. of Kirkland, Washington, undertook a baseline review of the status of two-stroke engines and competing technology. The emphasis was placed on larger, two-stroke, spark ignition (gasoline) engines for use in off-road vehicles notably snowmobiles, which have been economically important to small Montana communities. The baseline study also focused on the identification of improvements to two-stroke engines from a national and global perspective, especially with regard to lowered emissions and increased engine efficiencies. The global perspective takes into consideration environmental, institutional and technical barriers and opportunities for increasing market size of advanced two-stroke engines. Alternative technologies were also identified.

2. Under the direction and support of Howard Haines, Bioenergy Engineer, DEQ Planning Prevention & Assistance Division, NCAT staff concurrently developed a comprehensive website on clean snowmobile technology. The address of the forthcoming website is: www.cleansnowmobilefacts.com.

3. This study, ***The Status and Potential of Two-Stroke Engine Technology in Montana,*** is the third component and was conducted by Emily Miller, a technology market research consultant located in Moab, Utah. As the title conveys, this study examines the status and potential of two-stroke engines in Montana.

The service sector, and in particular tourism and recreation, are major industry sectors in Montana and the two-stroke engine has traditionally been used in winter (snowmobiling) and summer (marine and personal water crafts and off road vehicles) recreation. Increasingly environmental pressures are forcing changes in these recreation vehicles. In brief, there is a great deal at stake for the local and state tourism-based economy. To begin to address these issues, the extent or absence of two-stroke engine technology development within Montana are reviewed and discussed along with the statewide marketplace for two-stroke engines.

II. STATUS OF TWO-STROKE ENGINE DEVELOPMENT IN MONTANA: END-USE APPLICATIONS, MARKET CHARACTERIZATION AND STAKEHOLDERS

Research & Development and Manufacturing

This initial aim of this study is the identification of direct linkages in Montana to two-stroke engine technology development. Typically, research and development (R&D) in engine design and/or subsequent manufacture and sales would be found within the manufacturing industry and/or spin-offs from the university system. This study's author could find no R&D or manufacturing of two-stroke engines. Emission studies within Yellowstone National Park were conducted by the University of Denver. Details follow.

The College of Engineering at Montana State University, located in Bozeman, has Montana's only post-graduate level mechanical and industrial engineering program, and to date has had no involvement in two-stroke engine development. In fact, the State of Montana is one of the sponsors of the Clean Snowmobile engineering student competition, which has just completed it's second year (please see http://www.sae.org/students/snow.htm). Professor Doug Cairns of the College of Engineering says that "We were conspicuous in our absence." He explained that funding sources and faculty advocation of a project area must exist, and at the time of this study (May 2001) none have in the area of advanced two-stroke engine development.

Montana State University Northern, in Havre, Montana, has an automotive technology degree program within its College of Technical Services, but no program in two-stroke gasoline engine technology.

WestStart—Western Systems, Technologies & Advanced Research for Transportation– was established in February 1999 as a consortia of 13 western states (including Montana) and three Canadian provinces to promote advanced transportation technology. Montana was briefly considered as a possible site for an advanced transportation business incubator. However this concept never materialized due to Montana's low score on basic siting criteria such as access to markets and strong local financial support.[3] WestStart staff members did express considerable interest in the Yellowstone snowmobile situation; believing that a successful solution in an area with such high national visibility could increase awareness and interest in advanced transportation technology.

From an industry perspective, there are several small Montana-based companies involved in the design or manufacture of snowmobile performance products, but none involving engine design. The largest is *Dynojet Research, Inc.* established in Belgrade, Montana in the 1970s and now the manufacturing base for fuel injection performance products. The company moved its headquarters to Las Vegas, Nevada and its 80 employees are roughly split between the two locations. A company engineer, Jeff Todey, says that the company is hoping and anticipating that four-stroke engines will increase in the snowmobile marketplace and this would benefit Dynojet's fuel injection products.

Another company, *Northern Lites Inc.* of Columbia Falls, Montana, designs and fabricates lightweight snowmobile components such as brakes that are used in high performance snowmobiles and competition motorcycles. The company, started by racecar driver Dennis Kegel, has gone after a narrow aftermarket niche, and employs between 2 and 6 employees. Sales are said to be "way below one million." Kegel believes that two-stroke engine technology must change and reduce the smoke and noise levels. He also asserts that four-cycle engines will become the technology of choice for family snowmobile touring.

Crazy Mountain Extreme in Clyde Park, Montana is another small producer of high performance aftermarket snowmobile products. The company also builds ultra high performance snowmobiles, using existing commercial brands such as Polaris as the base technology. These limited production sleds are priced up to $24,500 or about four times the cost of the average snowmobile.

Montana Applications, Market and Stakeholders in Two-Stroke Engines

Despite the lack of direct linkages with the design and development of two-stroke engine technology in Montana there is a strong interest in and use of two-stroke engines in Montana particularly from the tourism and recreation sector. Even though Montana is 44th in population density, it ranks 11th in the absolute number of snowmobile registrations nationwide. As many as 95,000 Montanans may be snowmobile recreationists—eleven percent of the 902,195 residents counted in the 2000 Census.

Two-stroke engines offer inherent advantages over conventional four-stroke engines of comparable size with respect to size, weight, cost and power. A two-stroke engine can have 40 percent fewer components and be 30 percent lighter than a four-stroke engine. What is probably better known about the (older) two-stroke engines are their high level of noise and emissions. Table 1. provides the number of registered Montana snowmobiles, all-terrain vehicles (ATVs)/off-road bikes, and personal watercraft (PWC).

Table 1. Montana Registrations

	1999	**2000**
Snowmobiles	20,761	19,462
ATVs/Off-Road Bikes	16,712	20,033
Personal Water Craft	4,520	5,131
Other Motorized Watercraft	46,237	42,114

Source: the Montana Title and Registration Bureau of the Department of Justice, Deer Lodge, MT

Snowmobiles

The most vocal and well-publicized group concerning two-stroke engines are those involved in the Yellowstone National Park controversy over access of snowmobiles powered with two-stroke engines within the park boundaries. Key proponents of private snowmobile use within the park are snowmobile manufacturers, national user advocate groups and some business interests within the community of West Yellowstone, Montana. In April, 2000, a federal ruling called for the elimination of snowmobiles from national parks, including Yellowstone. The International Snowmobile Manufacturers Association filed a lawsuit regarding the process and a settlement negotiation remains underway. Observers say the National Park Service is likely to maintain the ban scheduled to take effect in the winter of 2003-2004 to give snowmobile rental companies time to switch over to snow coaches, van-like vehicles that carry eight or more people at a time.

As a point of reference, the 1992-93 season was the peak year for snowmobiles within Yellowstone National Park with more than 77,000 snowmobiles entering the park which exceeded the projected number for the year 2000.[4] The general trend is that Montana snowmobiling is a growing sport *when the number of nonresident activity days were compared.*[5] From 1993 to 1998, activity increased by 20 percent over the period, from about 185,000 nonresident activity days in 1993-94 to over 222,000 in 1997-1998.
During the 1998-99 winter season, more than 62,000 snowmobiles and 1,300 snow coaches brought visitors inside the park. The coaches are required to meet the more stringent emission standards.

In an updated report scheduled to be published in June 2001, "*Snowmobile Contributions to Mobile Source Emissions in Yellowstone National Park*" by Dr. Gary Bishop, et. al. of the University of Denver, the author concludes that the emission rates speak to the need for the snowmobile industry to move away from two-stroke designs to more efficient four-stroke engines.[6] Specifically, Bishop's most recent study shows that snowmobiles account for 33% of the annual emissions of carbon monoxide and 82% of hydrocarbons in Yellowstone National Park using an equivalent best estimate for the summer mobile source emissions.

On April 23, 2001, the National Park Service announced that President Bush has allowed a law eliminating use of private snowmobiles in Yellowstone and Grand Teton National Parks to take effect as scheduled. The Administration's announcement was made in conjunction with Earth Day.[7] In a June 24th, 2001 ***New York Times*** article,[8] it was reported that the Bush administration may be preparing to reverse its prior decision to ban private snowmobiles in Yellowstone National Park. Those close to the negotiations with the snowmobile manufacturers, say an agreement is likely to allow a limited number of snowmobiles equipped with new technology engines and that the industry says are cleaner and quieter.

This latest action is likely to be hotly contested by environmental groups who claim that public opinion is on their side based on a recently conducted national poll.
The results of the Zogby International poll conducted may 14th to May 18th, 2001 are included in their entirety below:

1) *Do you strongly support, somewhat support, strongly oppose or somewhat oppose allowing the use of jet skis, dirt bikes, snowmobiles, and other off-road vehicles in America's national parks?*

- Strongly support: 12%
- Somewhat support: 17%
    - **Support: 29%**
- Somewhat oppose: 26%
- Strongly oppose: 41%
    - **Oppose: 67%**

2) *The National Park Service has a rule prohibiting the use of jet skis in national parks. Knowing this, do you strongly support, somewhat support, strongly oppose or somewhat oppose prohibiting the use of jet skis in our national parks?*

- Strongly support: 46%

- Somewhat support: 14%
    - **Support: 60%**
- Somewhat oppose: 14%
- Strongly oppose: 23%
    - **Oppose: 37%**

3) *The National Park Service has decided to phase out the use of snowmobiles in Yellowstone National Park. Do you strongly support, somewhat support, somewhat oppose or strongly oppose the Park Service's decision to phase out the use of snowmobiles in Yellowstone?*

- Strongly support: 47%
- Somewhat support: 19%
    - **Support: 66%**
- Somewhat oppose: 17%
- Strongly oppose: 12%
    - **Oppose: 29%**

4) *According to the manufacturers, the next generation of snowmobiles will be cleaner and quieter than existing models. Conservation and recreation groups say that even if snowmobiles are somewhat cleaner and quieter, it will not stop the threat they pose to public safety and wildlife. Do you think that the newer machines should be allowed in Yellowstone National Park, or do you think that the Park Service should continue to phase out snowmobiles in Yellowstone?*

- Continue to phase out: 70%
- Allow snowmobiles: 24%

Source: www.earthisland.org/bW/PLNTWCpoll.html

Estimated Economic Impacts of Snowmobiles in Montana

The most concentrated direct economic impact of the snowmobile ban will be felt by the businesses in West Yellowstone, Montana. The University of Montana Bureau of Business and Economic Research estimated[9] that in 1998, non-resident snowmobilers spent about $200 per activity day statewide, including food, lodging, and often, snowmobile rental costs. In total, nonresident snowmobilers spent over $44 million dollars in Montana during the 1997-98 season for daily personal expenses and *it is estimated that 75% of all nonresident snowmobiling occurred within Yellowstone National Park for an estimated $33 million in local expenditures.* Table 2 details the estimated aggregate nonresidential expenditures of snowmobilers in Montana.

Table 2: Total Nonresident Expenditures of Snowmobilers Throughout Montana, 1997-98

Gas for snowmobiles	$2,842,851
Gas for transportation	3,206,006
Lodging	15,657,962
Eating & drinking places	10,921,362
Grocery and convenience stores	2,112,087
Entertainment and recreation stores	2,118,771
Other retail	2,698,035
Snowmobile dealers and repairs	**4,014,748**
Total nonresident expenditures	$44,131,036

The impact of snowmobile related spending could also be demonstrated in terms of jobs and income. The Bureau estimated that nonresident snowmobilers generate over $11 million per year in labor income for Montanans — or about 800 full and part-time jobs. It is further estimated that one-quarter of these economic impacts occur in the West Yellowstone area. Therefore, 25 percent of $11 million equates to $2.75 million per year in labor income and about 200 full and part-time jobs. Snowmobile rentals and repairs in West Yellowstone amount to $1 million annually. Finally, in West Yellowstone, 28 to 30 percent of resort tax revenues are collected in the winter.

Approximately 25 percent of the nonresident spending becomes direct labor income for Montanans - income earned by people who work in lodging places, eating and drinking establishments, and other businesses that service tourists. The remaining percentage is spent on items that must be imported into Montana for sale such as film, groceries and clothing. In addition to state income tax generated by service employees, the state treasury gains an estimated $1 million in revenue from the Montana Highway Trust Fund from the state gasoline taxes.

Yellowstone Stakeholders:

Opponents of a Snowmobile Ban:

Bill Howell
Yellowstone Arctic Cat
W. Yellowstone, MT
406/646-7365 (w) –7475 (h)

Bill Howell is co-owner of the West Yellowstone Conference Hotel with 123 luxury rooms and a 10,000 square foot conference center as well as Yellowstone Arctic Yamaha rentals and sales. In anticipation of the tightening regulations on snowmobiles, Howell introduced the first commercially available four-stroke Arctic Cats in time for the 2000-2001 season. Fifty sleds were made available as rentals and 50 more will be added prior to the 2001-2002 season. The customer response was reportedly positive, and Howell says "It is a comfort riding sled that an aging population will appreciate, as well as the lower maintenance and much better fuel efficiency." He says that the ten to fifteen percent price differential can be recovered quickly—

within a year or two. He speculates that the two-stroke engine as we know it probably won't exist (in the future).

One of Arctic Cat's primary competitors, Polaris, is going to introduce its prototype four-stroke snowmobile in time for the 2001-2002 season. Only 150 will be produced for the first season, but plans are to ramp up production for subsequent seasons.

Gale Loomis
Traveller's Snowmobile
West Yellowstone, MT
406/646-9332

Another of the largest snowmobile rentals and dealers in West Yellowstone, Traveller's is also the exclusive Polaris dealer for that sales territory. Loomis says that his rental business is planning to offer up to 100 of the new four-stroke Polaris snowmobiles—or one-half of Polaris's total prototype inventory for the upcoming season. At the time of this report (2001), Loomis feels that US snowmobile manufacturers were resistant to change which manifested itself in an arrogance. He points out that Polaris is building its four-stroke model from scratch, unlike Arctic Cat, and the company has committed substantial funds in R&D.

Traveller's Snowmobile wanted to equip fifty of its fleet with the prototype retrofit kit for reducing snowmobile emissions that had been developed by Atomized Fuel Technologies, Inc. (please see www.aftcarbs.com). The company, AFT, was contacted by the Chrysalis Technology Group, Ltd. in the two-stroke engine baseline study and is included under the report section ***Potential Solutions.*** In brief, the intent is to offer kits for retrofitting engines of major snowmobile manufacturers with atomizing carburetors and catalytic converters at a cost of about $750. AFT carburetor and catalyst technology was fitted to one of Traveller's Polaris 550 snowmobile engine, and tested by an independent testing laboratory. Since the laboratory results were positive, Gale Loomis intended to purchase fifty retrofit kits, but abandoned the project when a purchase price could not be agreed to between Travellers and AFT.

Another significant stakeholder, the **BlueRibbon Coalition,** aims to keep federal land open to multi-use and in particular, OHVs through legislative lobbying activities and litigation. Within the Yellowstone area Vicki Eggers is the Blue Ribbon Coalition Outreach and Education Specialist. Vicki Eggers said that a recent trip to the east coast reminded her of the importance of informing people about what was really happening in Yellowstone National Park and that the snowmobilers were not harassing wildlife as many of the public believed. Contact information is:

National Membership, 1-800-258-3742, www.sharetrails.com

Vicki Eggers, 406/646-9646 email: viki@gomontana.com

Proponents of a Snowmobile Ban:

Jon Catton, Communications Director
Greater Yellowstone Coalition
Bozeman, MT
406-586-1593
www.greateryellowstone.org

The Greater Yellowstone Coalition (GRC) operates from private foundation and donor funding that amount to about $2 million/year. Although the defense of the National Park System final ruling is a high priority of the GRC, this issue is "one of many" for the organization. According to Catton, even if snowmobile emissions and noise levels were reduced, the ban would still stand due to their adverse impacts on wildlife and health of workers *unless* the Final Rule is overturned. As of the time of this writing, the snowmobile manufacturers as represented by the International Snowmobile Association were in closed negotiations with the Department of Interior in response to the manufacturers' lawsuit.

Other environmental groups with a vested interest in the outcome of the national parks snowmobile and jet ski bans, with offices in Montana include:

Montana Chapter of the Wilderness Society
Bozeman, MT
406/586-1600
Contact: Bob Ekey
www.montanaws.org

Montana Wilderness Association
Madison-Gallatin Alliance (one of six chapters)
Bozeman, MT
406/582-8600
www.wildmontana.org

National Parks Conservation Association
Helena, Montana and Washington, DC
Contact: Tony Jewett, Helena 406/495-1560
Kevin Collins, Washington, DC 202/454-3392
www.npca.org

Kevin Collins, legislative liaison for the National Parks Conservation Association provided testimony on July 13, 2000 to the US House Small Business Committee's Subcommittee on Tax, Finance and Exports. The testimony argues that a ban on snowmobiles will not impact the local economy of West Yellowstone as much as the community has estimated. Below is an excerpt of his testimony:[10]

> "The economist on contract with the Park Service for economic analysis for the EIS recently conducted an economic impact assessment for the five surrounding counties. He found that the impact to West Yellowstone would be barely perceptible, even without mitigating efforts such as expanded marketing to attract other winter visitors. (John Duffield, Bioeconomics, Inc.)
>
> The economic analyses for the snowcoach only alternative (G) were computed in two ways. Each was based on an assumed 33 percent reduction in winter visitors, with 37

percent of nights spent in West Yellowstone (out of the five surrounding counties). Local multiplier effects are included. One method predicted an approximately $4.5 million impact.

A second method estimated an approximate $5.2 million impact. In economic terms, these two figures are so close as to be virtually the same.

The winter economy in West Yellowstone has been stable since the 1980s, with no significant growth[3]. In contrast, the summer economy has been growing steadily within normal economic fluctuations. The local economy is driven by park visitors, and as a whole (summer and winter) has been growing at 10 percent per year because of summer growth.

Significantly, there have been fluctuations of up to 15 percent in one year from which the economy has recovered without adverse or lasting effects. For this reason, Duffield categorized the potential $5-million loss to West Yellowstone's winter economy as inconsequential to the economy as a whole and not involving adverse, lasting impacts. Furthermore, with an aggressive marketing scheme to attract new and replacement visitors and an expanded fall shoulder season, the dip in winter revenue can be mitigated further".

[3] It is noted that Duffield's analysis was based on the resort tax and exludes such revenue generators as snowmobile sales and rentals. Taking account only of the drop in room rentals, Duffield's work estimated a $8.9 to $11 million reduction in locally generated business.

Snowmobiles, Other Areas of Montana

The 1998 BBER study estimated that ten percent of Montana households owned one or more snowmobiles. Translated into the number of recreationists, BBER says the data suggests that as many as 95,000 residents are snowmobile recreationists. Residents identified the number one issue facing snowmobilers as maintaining open access to public lands. (Impact on the environment was cited as the number one issue by less than ten percent of the snowmobile population surveyed).

The Montana Snowmobile Association was also contacted and has a broader interest in maintaining access to federal lands but is still a stakeholder in Yellowstone National Park.

Fay Lesmeister, President
Montana Snowmobile Association
Fort Shaw, MT
406/264-5393

The Montana Snowmobile Association has between 1,800 and 1,900 members. Lesmeister says that their group is pushing for quieter snowmobiles and for better gas efficiency. He believes that the four-stroke engine snowmobile will be the future direction and is ideal for trail riding and most use in the Midwest and the Eastern US. He acknowledged that the drawbacks are a heavier sled with greater mechanical complexity. Most snowmobilers trade in their snowmobiles every four years or less to get the latest technology. Two-stroke snowmobiles, he believes, will have continued market share for mountain travelers.

Because snowmobiling in Montana is relatively dispersed, the exception being the Yellowstone National Park area, the stakeholders are generally the 32 local snowmobile groups (see www.mtsnow.org) and chambers of commerce in the communities where there are nonresident snowmobile recreationists. These areas include the Big Hole Valley, Lookout where Idaho and Washington residents make day-trips; and in northwestern Montana where Marias Pass and Eureka draw some limited Canadian visitation. Smaller numbers of nonresident snowmobilers also visit Cooke City, Lincoln, and Seeley Lake.

Returning to the 1998 snowmobile study conducted by the BBER, the economic inflow into these areas (excluding West Yellowstone) from expenditures of nonresidents are estimated to be $33 million a year and the creation of 600 full and part-time jobs for Montanans.

In concluding this section identifying the stakeholders in Montana snowmobiling, it is interesting to note that the most frequently cited issue of all snowmobilers (resident and nonresident) is access to snowmobiling areas with safety factors the second most common issue. Less than 5% of respondents to the survey identified smoke emissions or noise issues. It is the sense of this study's author that there is a discernible shift in attitudes about noise levels and emissions since the time that the BBER survey was conducted in 1998 driven in large part by the closure of some national parks and ongoing pressure by environmental groups to close additional federal lands. As a result, a cleaner, quieter snowmobile, two- or four-stroke, will have a more receptive marketplace.

Watercraft

Total motorized watercraft in Montana amounted to about 50,000 in 1999 of which approximately 33,400 are outboard motors, 12,100 are inboard motors, and 4,500 are personal watercraft according to the National Marine Manufacturers Association (NMMA) of Chicago. Jim Petru, statistics manager, also reports that Montana outboard engine sales ranged between 894 engines in 1997 and a high of 1,262 engines in 2000. He speculates that even today less than fifty percent of new outboard engines sold are not compliant with the EPA regulations scheduled to take effect in 1996. While the Honda engine is advertised to exceed EPA regulations, Honda is a relatively small market player according to Mr. Petru. The "Big Three" manufacturers, Brunswick, Bombadier, and Yamaha, are extremely closed mouth, even to the NMMA, about what percentage of their new model engine unit sales are in compliance with the stricter regulations. Another barrier is the substantially higher price of the four-stroke outboard engine as compared to a two-stroke engine—up to 50 percent more. Finally, Petru notes that two-stroke outboard motor engines are commonly in use for twenty or more years if maintained. In conclusion, it is probably safe to assume that the vast majority of the 33,400 outboard motorboats in Montana are older two-stroke engines.

Personal Watercraft

In 1996, the Glacier National Park Superintendent banned personal watercraft (PWC) from Lake McDonald. This was preceded by the July 1990 ban on PWC on Lake Yellowstone enacted by the Park Superintendent in anticipation of potential problems[11]. In the 1999 session of the Montana State Legislature, House Bill 626, *The Montana No Wake (Jet Ski) Law* was introduced and passed. In brief, it recognizing the growing conflict between PWC recreationists and non-users, it prohibits the use of PWCs on certain waters by rule of the Montana Fish Wildlife and Parks Commission, and establishes a 200-foot safety zone from the shoreline. It was enacted in June 1999. Since then, new legislation was introduced and passed to include additional provisions due to increasing public concerns.

Last year, the US National Park Service banned personal watercraft (PWC) from two-thirds of all National Parks. In a recent settlement (December 2000) between the US Department of Interior and the Bluewater Network, a project of the not-for-profit Earth Island Institute, (please see www.earthisland.org) the two parties agreed that the remaining 21 parks would be included in the ban unless the DOI could prove that the machines do not harm the environment. The story continues to unfold — in April 2001 the Secretary of the Interior, Ms. Gale Norton, ordered a temporary suspension of the ban and commenced a review of four national parks, all on the east coast.

These details are presented to illustrate the rapidly changing situation with major consequences for the personal watercraft industry. While the number of PWCs in Montana is considerably lower than snowmobiles—approximately 5000 or one-quarter of the number of snowmobiles based on registrations data from with the Montana Title and Registration Bureau in 2000—its data also shows that eighty percent of PWCs are five years or older. [12] While the two national parks prohibit PWCs, Flathead Lake, the largest freshwater lake wholly within the contiguous 48 states, and the Thompson Chain of

Lakes, all in northwestern Montana, remain open to PWC recreationists and are beginning to generate local controversy.

The Flathead Lake Monitor (Summer 2000 edition) states that....

> "Of all the problems, concerns and issues members (of the Flathead Lakers, a voluntary association of 1000 homeowners and concerned public—please see www.flatheadlakers.org) and the public bring up to the Flathead Lakers's board and staff, PWC top the list. We have heard stories of inconsiderate and dangerous operator behavior and wildlife harassment...We've also heard about long-term area residents responsibly and courteously enjoying using their PWC."

In response to the concerns the Association has formed a subcommittee and developed a survey of its 1000 members to research, develop and analyze options and make recommendations for addressing problems associated with PWCs. Larry Hanzel, Vice President of the Flathead Lakers Association, feels that the PWC noise level is the main issue, followed by safety. According to Board Member Rose Schwennesen there is increasing concern over the release of MTBE[13] in the lake's water, and concern that Montana will become a dumping ground for California's banned two-stroke engine-powered PWCs.

Region One of Montana Fish Wildlife and Parks also conducted public scoping on "motorized watercraft conflicts and opportunities" and of the 438 surveys returned 325 felt that a problem exists. The most frequently proposed solution was the placement of restrictions on PWCs.[14]

The PWC industry has responded to the increasing pressure for reduced noise and emissions levels with new models that lower emissions by 75% through use of fuel injection and variable exhaust ports or four-stroke engines. The Personal Watercraft Industry Association (please see www.pwia.org) states that many of the 1999 watercraft are 50 to 70 percent quieter than 1998 models. Manufacturers have achieved these reductions through the use of various techniques including intake/exhaust system redesign, active noise-canceling devices, engine/drive train isolation and additional noise suppression materials. Honda's four-stroke engine is pointed out as being notably fuel efficient and quiet.[15]

In sum, PWCs in Montana are a growing source of conflict and contention between users and non-users. Stakeholders include these two groups, as well as local and state officers and legislators, environmentalists, PWC manufacturers and rental/sales business persons.

All Terrain Vehicles/Off-Highway Vehicles

In 2000, the number of registered ATVs and dirt/trail bikes (referred to in combination as off-highway vehicles or OTVs) slightly exceeded the number of snowmobiles in Montana in contrast to recent years. [16] An estimated 12 to 13 percent of Montana households own one or more OTV—the same percentage of household owning snowmobiles.[17] However, this group is less cohesive and organized with only two associations in Montana (please see www.atvsource.com/clubs/state/montana) as compared to 33 state and local snowmobile associations. There are a number of unregistered vehicles used in ranching and other agricultural operations as well.

In 1996 the University of Montana Bureau of Business and Economic Research (BBER) was commissioned to estimated the economic benefits of OHV recreation in a ten-county area of southwestern Montana, using Boulder, Montana as the 'epicenter' of activity. The study estimated that the total annual expenditures for the study region was about $3.3 million, of which half was used in gasoline expenditures. By and large OHV recreationists were likely to make day trips. The author, Jim Sylvester, said in an interview for this study that the economic benefits were negligible or even negative after expenses for trail upkeep and enforcement were accounted for.[18]

As with snowmobiles and PWCs, more four-stroke OTVs are being introduced and sold due to their gas efficiency and lower noise and emission levels. However, those looking for a faster, lighter and more responsive vehicle for competition or mountainous terrain, favor two-stroke models.

Don Adador, the Blue Ribbon Commission Western Representative, estimates that about 60% of dirt bikes are two-stroke due to the attributes mentioned. In comparison, the newer four-stroke engine models are increasingly appealing to entry-level and general trail riders.

Despite repeated efforts to speak with the Montana ATV association representatives, no contact was made.

Forestry

Two-stroke engines are used in professional power chain saws utilized by Montana forestry personnel. According to the Montana Department of Labor's program on Occupational Employment Statistics most recent survey (1998) there were 1,983 'fallers and buckers.' [19] It was projected that by 2008, there will be a growth of 186 Faller and Bucker positions in Montana. These statistics give a good proxy of the approximate number of professional power chain saws in current and projected use in Montana.

Paul Uken, the Safety Ranger with the Montana Logging Association, says that they are beginning to see new power saws with emission controls. The woodcutters find them more difficult to keep adjusted and report there are more breakdowns and less power. As a result, Uken says that some of the men try to remove the emission controls.[20]

Dr. Martin Moss who is the Head of Engineering Quality Services of Stihl Power Tools, one of the largest chainsaw producers worldwide, was interviewed. Moss stated that the future direction of professional power saws is a mandatory tightening of emissions control as set forth by the US Environmental Protection Agency (please see: http://www.epa.gov/otaq/regs/nonroad/equip-ld/hhsfrm/f00007.pdf). He expects the price and the weight of handheld professional power saws to increase about ten to fifteen percent, and said that the increased weight will be especially unpopular to professional loggers who work ten and twelve hour days. While two-stroke engines will not be replaced with new technology, manufacturers are being forced to make major system changes in order to comply with the environmental regulations that began in California under its California Air Resources Board and is the model behind the US EPA regulations.

Mining Equipment

Two-stroke engines have been used in mining operations for portable air and water pumps and small compressors. However, according to Professor Philip Patton, instructor of mining methods and engineering at Montana Tech, the use of two-stroke engines today is rare. He says that they are not heavy or durable enough for commercial mining operations and that diesel engines are the norm. Based on approximately twenty-four hard rock mines in operation in Montana today, plus the miscellaneous “mom and pop” mines, Professor Patton estimates 100 two-stroke engines are in use today in Montana’s mining industry.

III. BARRIERS CONFRONTING TWO-STROKE ENGINE AND MARKET DEVELOPMENT IN MONTANA

Montana-Specific Barriers

1. ***Lack of a significant manufacturing base and infrastructure.*** Snowmobiles, personal watercraft, and off-highway vehicles are produced by a relatively small number of well-established manufacturers that are located in areas, e.g., southern California and Michigan, with an extensive manufacturing infrastructure already in place. Subcomponents parts and services, skilled labor, existing distribution channels and transportation access, and close proximity to major markets and population centers are some of the key ingredients of a vibrant vehicular manufacturing base.

   In contrast, the Montana economy is based primarily on agriculture, retail and wholesale trade and services (especially medical), construction, government and tourism related activities. While Montana is the fourth largest state geographically, its population of just over 900,000 is the size of many smaller American cities. In 2000, only 5.3 percent of the Montana labor force worked within the manufacturing sector. [21]

2. ***Lack of sufficient state economic incentives to attract existing smaller businesses.*** Given the state's limited manufacturing base and ability to attract large companies, the opportunities to attract small but growing ventures, such as companies that provide products for the after-market, may be more promising. As noted previously, Montana has a few businesses that design and manufacture after-market products for the high-performance segment of snowmobiles and OHVs. All of these are home-grown, involving Montana native or current residents.

Small innovative companies that produce aftermarket products such as emission and noise control retrofit kits would meet two mutually compatible objectives—providing new economic development opportunities in Montana and providing solutions to address noise and emission problems with the existing inventory of snowmobiles, PWCs and OHVs.

Typically efforts to attract such companies involve public/private sector partnerships and economic incentives to compensate the entrepreneurial firm for relocation. In Montana, according to the Department of Commerce's Business Recruitment Officer Quinn Ness, there are only limited direct financial state incentives that go to the local government participants in the Montana Certified Communities Program. This program provides matching funds of $5,000 to $25,000 to the local communities. A complete profile of Montana Business Incentives is included in the report Appendix. It is the author's opinion that efforts to target and attract innovative small manufacturers will require local community private/public partnerships. This topic is addressed further in Section IV, Potential Solutions.

3. ***Lack of advanced engineering programs addressing two-stroke engines at Montana's universities and technical colleges.*** At the time of this study (May 2001), there are no programs or centers of technical excellence in the area of advanced two-stroke engine design from which entrepreneurial activities can spin off. If one existed, Montana State University is the logical place for such a program.

   Typically university-based centers of excellence evolve out of a state's economic heritage, (e.g., Michigan universities and their advanced studies in automotive design, the University of Montana and its well-respected forestry program). Programs and centers also develop to meet the needs of the new information economy—such as the computer science programs in essentially all institutions of higher learning.

Advanced two-stroke engine design does not fit the first criteria—economic heritage— and it is questionable if there is a sufficient unmet need or 'sex appeal' for the formation of a new program in Montana. Dr. Doug Cairns of Montana State University said there needs to be funding and advocation for a new 'clean engines' program of study in Montana, and to date, neither exist.

Other Barriers

1. ***Technology-substitution that lessens demand for two-stroke engines.*** There is no doubt that four-stroke engines are becoming the technology of choice for recreation vehicles in markets with tightening environmental controls. While the manufacturers have been slow to change over, they have finally made the transition as well as making the necessary capital investment in research and development, and retooling their plants and equipment. And with additional capital outlays, one can expect greater sales and marketing efforts from the manufacturers to promote the newest technology and recover their investments.

   In terms of the effects in Montana, rental and sales will be most directly affected, but probably not adversely. Businesses have already begun to promote the advantages of the quieter and more fuel efficient four-stroke models of snowmobiles, PWCs and OHVs. It is likely that rental and sales businesses will carry a mixed inventory of two-stroke and four-stroke. The larger more profitable rental businesses already are accustomed to turning over their rental inventory frequently and getting in the latest models.

2. ***Federal regulatory issues likely to remain under pressure and the scrutiny of the public eye.*** The public has become more knowledgeable and concerned over the continued use of the old two-stroke technology. At the time of this writing, environmental groups and industry representatives are locked in litigation over the access for OHV's to public lands. The strong tensions that have developed are not likely to dissipate soon.

   These conflicts have caused some industry and traditional recreationists to rethink the issues of environmental emissions and noise levels and to publicly state their support for cleaner and quieter vehicles. This overall movement and support towards a cleaner engine will further encourage technology substitution or the redesign of the two-stroke engine. This could be a positive or negative impact on two-stroke engines depending on the future direction taken by the manufacturers.

   Two-stroke engines will continue to be favored by those looking for a higher performance and horsepower snowmobile to work in deep powder snow.

3. ***Negative public perception among the general public.*** One member of the pro-motorized access Blue Ribbon Coalition said that there was a misunderstanding by the general public about snowmobiles in Yellowstone National Park and their impact on wildlife (especially buffalo) due to misleading national media stories. A member of the Flathead Lakers Board of Directors said that there is concern that northwest Montana will become the dumping ground for the old models of PWCs now being prohibited by certain recreation areas such as Lake Tahoe, California. While these stories are different, they both convey a negative perception by members of the general public towards recreation vehicles and/or their operators.

The growing negative public perception towards land and water personal recreation vehicles is another source of major pressure on the manufacturers to change the negative public image by reducing the environmental impacts and encouraging more responsible behavior by the operators. In any event, the industry status quo of the last decade and a half is no longer being tolerated.

4. ***Manufacturers have been slow to embrace advanced two-stroke engine technology development.*** This is particularly true with snowmobile manufacturers. Only recently have snowmobile manufacturers come forward publicly with new two-stroke engine designs. By the second year of the ***Clean Snowmobile Challenge*** all four major manufacturers participated in contrast to the first year. While this student competition has only completed its second season, it has been very positive in terms of generating support and solutions to solving the issues of emission and noise of snowmobiles. The Clean Snowmobile Challenge has been covered by the national media and has generated excitement among the contenders. And perhaps most importantly, manufacturers are finally taking notice.

IV. POTENTIAL SOLUTIONS

There is no easy or obvious solution to the attraction or creation of innovative small manufacturers dedicated to the advancement of two-stroke engine technology in Montana. For this to possibly occur there would need to be a champion of the cause, possibly one of the local economic development authorities that could assemble a reasonable package of economic incentives combined with a 'quality of life bonus' (i.e., appealing to business people who are interested in more easily participating in outdoor recreation than is possible in industrial or populated areas of the country). It may also be possible to work with the existing small Montana manufacturers such as Dynojet Research Inc. to include environmentally beneficial aftermarket products to their offerings. Perhaps these companies could license technologies and forego the costly research and development phase. But foremost, there needs to be a dedicated champion of this technology development effort from the stakeholders and, in particular, the university community. Possible sources of funds and champions are:

- A Center of Excellence or a clearinghouse dedicated to advanced two-stroke engine development, housed at the National Center for Appropriate Technology or some other Montana-based organization interested in promoting energy conserving technologies
- Federal and foundation grant opportunities
- Private/public collaboration between a Montana-based Center of Excellence and a manufacturer(s) of advanced two-stroke engines

Preserving Montana's outdoor recreation activity in a way that doesn't further degrade the environment is of greatest importance in terms of longstanding economic benefits to the State and the residents of Montana. Adopting this goal may require some degree of technology substitution, i.e., to a four-stroke engine and the use of fuel injection on two-stroke models.

Supporting the participation of Montana State University's Mechanical and Industrial Engineering Program in upcoming Clean Snowmobile Challenges will have several benefits. If done properly, this could become a catalyst that raises the level of technical expertise within Montana. And in a state where entrepreneurial activities are often the best means to acquiring job satisfaction and security, students may decide to venture out and begin their own manufacturing business of environmentally friendly products. It has happened in computer software development.

Despite the adversity felt by some manufacturers of encroaching environmental controls and limiting access to certain public lands, a new market is simultaneously being created for quieter, safer, and more fuel efficient personal recreational vehicles. The introduction of this new product generation may appeal to more people who view it as a family activity that doesn't require rigorous physical conditioning (ie, the aging baby boomers who are looking to find suitable substitutions for more risky and strenuous recreational pursuits such as mountain biking or skiing). In short, out of adversity may come a larger more diverse customer base.

While Montana's stakeholders are extremely diverse in their specific objectives, they do share in the overall goal of maintaining Montana's natural environment and appeal. Actions should be continued to ensure that the old two-stroke engine is replaced with a cleaner, more efficient technology.

ENDNOTES

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[1] Zobgy International poll conducted May 14 to May 18, 2001 as reproduced by www.earthisland.org.

[2] Seelye, Katharine Q., "Bush May Lift Park's Snowmobile Ban," **New York Times**, June 24, 2001.

[3] An informal history of West Start and its involvement in Montana was provided by Mike Morris of the National Center for Appropriate Technology, Butte, MT.

[4] National Park Service. *Winter Use Plans: Final EIS for the Yellowstone and Grand Teton National Parks and John D. Rockefeller, Jr. Memorial Parkway,* National Park Service, Denver, CO 2000.

[5] Sylvester, James, T., **Snowmobiling in Montana—A 1998 Update,** Bureau of Business and Economic Research, University of Montana, Missoula, MT October 1998.

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[10] See http://208.226.12.12/media_center/testimonies/testimony071300.asp

[11] Interview with Chris Hansen, Yellowstone National Park enforcement operations.

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[12] Interview with Rose Schwennesen, Board Member, Flathead Lakers Organization.

[13] MTBE (methyl tertiary-butyl ether) is a volatile organic compound made as a byproduct of petroleum refinery operations by combining methanol derived from natural gas and isobutylene. MTBE is used as a gasoline additive, octane enhancer or oxygenate.

[14] ***Flathead Lake Monitor,*** Summer 2000 edition, page 5.

[15] Interview with Dr. Gary Bishop, University of Denver Department of Chemistry and Biochemistry.

[16] Montana Title and Registration Bureau, Deer Lodge, MT 406/846-6005.

[17] Sylvester, James, T., **Off-Highway Vehicle Recreation in Southwest Montana,** Bureau of Business and Economic Research, University of Montana, Missoula, MT, 1996.

[18] Interview with Jim Sylvester, Missoula, Montana, April 2001.

[19] Fallers are workers who fell trees and saw into specified log lengths, working alone or as a member of a team. The bucker saws trees into specified lengths after the faller has cut the tree to the ground.

[20] Interview with Paul Uken, Safety Ranger, Montana Logging Association.

[21] **Montana by the Numbers,** http://ceic.commerce.state.mt.us/Demog/Mtbynumb.pdf

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APPENDIX:
Montana Business Incentives

MONTANA BUSINESS LOCATION - POTENTIAL FINANCING OPTIONS

The purpose of this information is to outline potential sources of grant and lower cost fixed rate interest loan funding for relocation projects in Montana. The funding sources are a combination of local, state, and federal loan and grant programs and tax incentives. Many community areas have major universities, international airports, existing industrial parks with available land, railroad access or potential access, interstate highways, natural and cultural amenities and sophisticated local governments capable of arranging complex financial and tax incentives for new business expansion.

The following programs and sources of funding may vary in size and applicability depending on the provision of more detailed project information and site location. The funding sources are organized by grants and quasi-grants, tax incentives, and loans.

GRANTS AND QUASI-GRANTS

Creation of Tax Increment Financing District

State law provides for the creation of a tax increment financing industrial district for industrial development projects. A local government may issue bonds for a wide variety of development purposes such as: financing land acquisition; industrial infrastructure; rail spurs; buildings; and personal property related to the public improvements.

The incremental increase in the tax base over the unimproved value before the project was developed can be committed to repayment of the bonds. The bond financing can essentially be considered a grant by the business because taxes paid will directly benefit the district. The actual amount of bond financing available is based on the ability to repay the bonds with the incremental value of the tax increase.

Montana Board of Investments

Infrastructure Program

The Montana Board of Investments (MBOI) may loan funds to a local government for public infrastructure improvements. The local government repays the loan from fees and assessments to the business using the infrastructural improvements. The business may write off up to 100%
of the related fees and assessments paid to the local government on its Montana income tax as it documents the related job creation. The infrastructure improvements function like a grant to the business as a direct reduction of project development costs. The business to be assisted is analyzed by MBOI and the final decision is based on the

strength of the business project being financed. The actual benefit to the company is limited by the number and quality of jobs created and the ability of the business to write off the tax credits on its actual income tax liability. Infrastructure loans are limited to $16,666 per job created as a result of the project. The minimum loan amount is $250,000.

Aerospace and Technology Infrastructure Development Program

The State of Montana may issue and sell up to $20 million in general obligation bonds for aerospace transportation and technology infrastructure development projects. The state would own the improvements funded and would lease the infrastructure to the local government tax increment financing district or the business being assisted. The lease amount would be set at a nominal fair value taking into consideration job creation and overall tax revenue generated by the project. The statute provides for the principal and interest payback of the bonds from increased state taxes generated by the projects funded.

Montana Department of Commerce Economic Development Finance Program (CDBG)

Up to $400,000 in grant funds is potentially available for local grant applications involving city and county governments from the Department of Commerce. Depending on the potential size of the project, it is possible to combine grants to the county and the city for a total of $800,000 in potential grant funding in special circumstances. The grant funds may be used for infrastructure and for the direct cost reduction of training expenses incurred by the company. The amount available is limited to $5,000 per employee trained and $15,000 per full time-equivalent employee hired for infrastructure projects. In addition, many localities have local CDBG funds potentially available for projects.

TAX INCENTIVES

New or Expanding Industry Wage Credit

A new or expanding manufacturing corporation may receive a corporation license tax credit of 1% of wages paid to new employees for the first 3 years of operation and expenses.

Local Option Property Tax Incentives

New and expanding industries may be taxed at 50% of taxable value for the first 5 years after a construction permit is issued. The tax rate is increased incrementally over the next 5 years to 100% after ten years at the option of the local government.
NOTE: A lower tax rate reduces the capacity for tax increment bonding.

There are numerous specialized tax incentives which can be researched with the Department of Revenue on a case by case basis.

LOW INTEREST LOANS

The Montana Board of Investments (MBOI) may participate in bank loans up to a maximum of approximately $6.4 million. MBOI may participate up to 80% of a bank loan made in Montana. The MBOI participation can provide for fixed loan rates as low as approximately 5-6% depending on the strength of the borrower and the number of jobs created. Interest rates may be lowered by up to 2.5% for the initial $6.4 million if a business project involves the creation of up to 50 new jobs paying higher than an established benchmark. The bank portion of the loan is priced by the lending institution and may be fixed or variable.

MBOI may also purchase federal loan guarantees, such as Rural Development Business and Industry Guarantees, and provide the same low fixed rate advantages and job creation interest rate reductions to the business as the loan participation program described above. MBOI may participate at a higher level if loan guarantees are available for loans exceeding the $6.4 million limit. Although the interest rate would still be fixed for loan participations exceeding $6.4 million, the job creation interest rate reduction would not apply for the amount exceeding $6.4 million.

New $50,000,000
2% Interest Funding Set-aside

Businesses producing value-added products and commodities and that project the creation of 15 or more additional jobs are eligible to apply through a bank for an MBOI loan participation. There is the potential for an eligible business to receive up to $6.4 million with a 2% fixed interest rate for the first 5 years of the loan term. Participating banks may not require personal and/or corporate guarantees. There is no provision for job creation based interest rate reduction because of the low initial rate.

Montana Department of Commerce Economic Development Finance Program (CDBG)

Loans of up to $400,000 can be made to businesses creating new jobs in Montana. Up to $15,000 dollars is available for each full-time equivalent employee projected to be hired as a result of the business project financed. The current interest rate is a fixed 8% and is loaned over variable terms depending on uses of funds. Payment deferrals are negotiable and loans can be subordinate to other lenders if necessary and appropriate for the project to proceed. Local governments would apply on behalf of the business and receive a grant from the Montana Department of Commerce. The local government would provide the granted funds as a loan for the business.

LOCAL DEVELOPMENT PROGRAMS

All major, and most smaller, communities in Montana have local development corporations with local programs that can enhance total finance packages and assist with business location issues. The Department of Commerce regularly works closely with local development corporations to assist with business location projects by combining resources as much as possible.

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Planning, Prevention and Assistance Division
Montana Department of Environmental Quality

Comparison of Carbon Monoxide Emissions from Snowcoaches, 1997 and 2001 Snowmobiles, and 2001 Clean Snowmobile Challenge New Technology Applications

INTRODUCTION

The Montana Department of Environmental Quality (DEQ) conducted this modeling analysis to compare potential emissions from snowcoaches and different types of snowmobiles. The purpose of this analysis was to compare carbon monoxide emissions from snowcoaches, older snowmobiles, and technologically improved snowmobiles using the latest and best estimates of CO emissions. This analysis builds on information that was presented previously by DEQ in the "Preliminary Air Dispersion Modeling Analysis of Yellowstone National Park West Entrance Wintertime Carbon Monoxide Emissions" (Cain and Coefield, 1999).

Results are presented from two of the alternatives that were considered in the "Winter Use Plans Final Environmental Impact Statement (FEIS) for Yellowstone and Grand Teton National Parks, and the John D. Rockefeller Jr., Memorial Parkway." These alternatives involved snowmobiles as the predominate transportation vehicle and snowcoaches as a replacement for all vehicles entering the park. Additional analysis is presented using data that were collected in March 2001 on a commercially available two-stroke snowmobile, and on two-stroke and four-stroke snowmobiles that were modified by university students to reduce noise and emissions.

This analysis is presented for consideration as part of the Supplement Environmental Impact Statement (SEIS) process for the winter use in Yellowstone and Grand Teton National Parks, and the John D. Rockefeller Jr. Memorial Parkway. The State of Montana has been one of the cooperating agencies with the U.S. National Park Service (NPS) for both the SEIS and FEIS.

CLEAN SNOWMOBILE CHALLENGE

In an effort to reduce snowmobile exhaust and noise, the Society of American Engineers (SAE) has organized a new intercollegiate design competition, the Clean Snowmobile Challenge (CSC). From this competition, innovative designs to improve snowmobiles have surfaced, showing the potential for new machines in the future.

The Clean Snowmobile Challenge 2001 provided university teams the latest opportunity to modify existing snowmobiles to operate cleaner and quieter. University teams used both 2- and 4-stroke engine technologies in their student-modified snowmobiles. However, given the short (4-month) time frame to adapt the vehicles, many teams had snowmobiles with poor tuning and clutching, resulting in a wide array of emissions.

The Clean Snowmobile Challenge 2001 emissions event was conducted at Flagg Ranch, Wyoming; elevation is approximately 2,092 meters (6,800 feet). Test ambient temperatures ranged from 15 to 35 degrees Fahrenheit. Southwest Research Institute conducted the emissions testing (Fussell, 2001). Test equipment included a chassis dynamometer supplied by Dynaojet of Bozeman, Montana and laboratory–grade instrumentation supplied by Southwest Research Institute, San Antonio, Texas. Fuel type for the sleds in this analysis was an ethanol blend (E-10).

Data from some of the student-modified machines were eliminated due to machine failure to meet the minimum requirements of the competition. The CO emissions analysis was conducted using a range of emissions rates for each engine speed from the top five placing snowmobiles since each machine was so unique in design (White et al., 2001). However, this range was sometimes skewed, as in the idle CO emissions factor for 4-strokes where one team did not yet have their idle mode properly set. All sleds with catalytic converters were seasoned during a 100-mile run prior to the emissions event. Most of the teams used Original Equipment Manufacturer's catalytic converters, but only two teams were able to provide an estimate on the longevity of the equipment for this snowmobile application. A chart showing the emission factors for the individual machines used in this analysis is attached as Appendix B.

The Clean Snowmobile Challenge 2001 results show the kinds of improvements in emissions that are possible from two and four-stroke engines used in snowmobiles. It is important to note that these machines are not available on the market today. Information on new technology four-stroke machines would be a useful comparison for this analysis. That information was not available when this analysis was conducted, but it will be analyzed if it becomes available.

FEDERAL AND MONTANA HOURLY CO STANDARDS

The 1-hour National Ambient Air Quality Standard (NAAQS) for CO is 35.0 parts per million (ppm) not to be exceeded more than once a calendar year. The hourly Montana Ambient Air Quality Standard (MAAQS) is 23.0 ppm for CO not to be exceeded more than once a calendar year, 34 percent less than the Federal standard. The Montana standard was based on an epidemiological evaluation conducted by Montana during 1979-1980. Other states with a different hourly CO standard than the federal one are California and New Mexico, 20.0 and 13.1 ppm, respectively.

CO HOT SPOT MODELING

An U. S. Environmental Protection Agency (EPA) "hot spot" or intersection model, CAL3QHC, was used to predict the CO concentrations from vehicles entering and exiting the park entrance during wintertime conditions. CAL3QHC is a line source dispersion model with a traffic algorithm for estimating vehicular queue lengths at signalized intersections. It predicts the concentrations of inert air pollutants such as CO from motor vehicle exhaust along the sides of the roadways one hour at a time at user-defined locations (receptors). Wind direction (from which it is coming from) can be varied from 0 to 360 degrees (at 5-degree increments) to determine the highest 1-hour CO concentration. It is considered a screening model that provides quick, worse case analysis using several broad assumptions including meteorological and site characteristics to estimate CO concentrations. Other air pollution models are available, referred to as "refined", for a more complete, in-depth analysis that requires on-site meteorological data.

MODELING OVERVIEW

The screening model, CAL3QCH, estimates the maximum 1-hour CO concentration using one hour of data, the values are not absolute. To obtain concentrations more representative of the true atmospheric CO concentrations of an area of interest, a more refined model must be used. These more refined models use hourly vehicle data and on-site meteorology including wind direction and speed, ambient temperature, and atmospheric mixing heights. Also, at a minimum, an entire day is modeled. Topography is further characterized by defining the receptors (the locations where the model estimates the concentrations) with elevations relative to the roadway. The signalization cycle (stop and green times) used in this analysis also needs to be further studied since estimates were used. Therefore, the results from this modeling analysis should only be used as relative values for comparison among the scenarios examined specifically in this investigation.

MODELING VERSUS MONITORING

The model predicts the maximum 1-hour CO concentrations at each location (receptor) and wind direction that has been manually entered by the user; these locations represent areas where the public has access. According to the model requirements, these receptors cannot be located within 10 feet (3.0 meters) of the traveled roadways or within tollbooths (kiosks), intersections, or crosswalks. Another receptor is included to represent the local CO monitoring station if one exists. Monitoring stations are placed near the sources of pollutants according to stringent EPA siting criteria. For a microscale CO site, such as the one located at the west entrance of the Yellowstone National Park, the inlet to a CO measurement instrument must be between 2 and 10 meters (7 and 33 feet) from the roadway edge and sufficiently distant from obstacles that obstruct air flow such as buildings and vegetation to assure representative data.

The locations of the highest 1-hour CO concentrations predicted by the model will not necessarily correspond to the location of the CO monitoring station receptor. The type, number, and activity of the vehicles (entering or exiting the park entrance), and wind direction will affect where the model calculates the maximum CO concentration.

Compliance with the hourly national and Montana CO standards is determined by the second highest hourly concentration, but the model only provides the first. Therefore, the model results can only be applied as a rough estimate whether compliance with the standards will occur. Also, air pollution modeling focuses on the public's exposure to air pollution so the highest CO concentration predicted, regardless of the location, is used for comparison to the standards. In reality, the data collected at the monitoring inlet will determine the area's compliance status.

CO BACKGROUND CONCENTRATION

Generally, a background CO concentration must be added to the CAL3QHC modeling results since this model evaluates only the direct effects of CO emitted by the vehicles included in the model input file. The results do not include CO impacts from all other sources of CO that are close enough to affect the air quality of the area of interest. Indirect impacts from these sources are estimated and added to the model results as "background" CO for the final highest 1-hour concentration. These sources include CO from residential wood burning and other vehicle emissions outside the immediate area. The CAL3QHC model also does not have any way to account for residual CO still remaining in the atmosphere from the previous time period. These residual CO effects must also be factored into the background value.

Generally, a CO background concentration is obtained from direct measurement at the site of interest. In October 1998, DEQ installed a microscale carbon monoxide monitoring station (30-031-0013) on the northeast side of the Yellowstone National Park west entrance. Due to machine malfunction, minimal wintertime data were collected. The highest hourly CO concentration, 18.1 ppm (parts per million) was measured on February 13, 1999 for the 5:00 to 6:00 P.M. period. The CO concentrations decreased to 3.1 ppm for the 11:00 P.M. to 12:00 A.M. period. Reviewing the data and using DEQ professional judgement, a 5.0 ppm background CO concentration was selected to represent the worse case residual impact of CO during stagnation periods.

CARBON MONOXIDE DATA

Exhaust carbon monoxide (CO) emissions were compared from the snowcoach alternative to CSC 2001 snowmobiles and a 2001 commercially available snowmobile using the "hot spot" intersection model described above. Baseline CO emissions were estimated using the ISMA-approved 5-mode steady state laboratory methods with a 1997 fan-cooled Polaris 500cc engine (White et al., 1997), and from field evaluation of a 2001 Polaris fan-cooled 550cc 2-stroke snowmobile.

The major differences between the laboratory and field baselines were that the laboratory data were developed at 20 degrees centigrade (C) at sea level with an engine dynamometer on an older snowmobile engine using gasoline. The field data baseline information were taken at cooler and higher elevation ambient conditions on a snowmobile operating on ethanol blend fuel (E-10) and tested with a chassis dynamometer system. The 2001 snowmobile was selected randomly from the fleet of 50 snowmobiles at Flagg Ranch, Wyoming. Emissions data from CSC 2001 were also reported as brake-specific measurements of grams per kilowatt-hour as required by U.S. Environmental Protection Agency (EPA) for off-road engines, but also included dynamometer (snowmobile) track speed.

The hot spot model requires data in grams of pollutant per unit of distance (grams of CO per mile or grams of CO per hour for idling). The Pollution Prevention Bureau, DEQ, converted the snowmobile CO emissions data from the grams per kilowatt-hour to grams per mile using the raw data (White et al., 1997; Southwest Research Institute,1999) for model input. Data for the idle mode were not modified as it is reported in grams per hour.

Carbon monoxide emission factors for clean technology snowmobiles of the CSC 2001 were developed by dividing grams per hour (of emissions) for each mode by the track speed (MPH). The Pollution Prevention Bureau extrapolated the emissions rates to grams per mile. This was done by plotting grams per mile against the track speed in miles per hour with the curve extrapolated to slower speeds. For the slowest speeds, the emissions rate was assumed to be proportional to the reduction in speed. In other words, the emission factor for 5 miles per hour was half that of 10 miles per hour emission factor for a given machine.

ASSUMPTIONS

There were numerous assumptions made in the modeling demonstration including the following:

Receptors (locations where the model will estimate the CO concentration) were located on both sides of the roadway.

Wind direction varied from 0 to 360 degrees, at 5-degree increments.

All vehicles moved at a constant rate when entering the park.

Morning activity involved no departing vehicles.
Cycle time for vehicles excluding snowmobiles simulated a roadway intersection: 68 total seconds, 60 seconds red time, and 8 seconds green time.
Cycle time for snowmobiles simulated a roadway intersection: 30 total seconds, 24 seconds red time, and 6 seconds green time.

Alternatives were developed for both snowmobiles and snowcoaches, with several different scenarios developed for snowmobiles.

Snowmobile Alternatives

The following assumptions were used for each of four snowmobile scenarios. The scenarios are described at the bottom of the assumptions.

Worse Case Morning Period: 8:00 – 9:00 A.M.
600 Gasoline Snowmobiles, 10 mph; traveling emission factor = 395.0 grams per mile (gm/mi.) (Note: these snowmobiles do not stop to purchase day pass – express lane).
300 Gasoline Snowmobiles, 5 mph; traveling emission factor = 800.0 gm/mi.
    Idling emission factor = 1,000.0 grams per hour (gm/hr)
10 Gasoline Snowcoaches, 5 mph; traveling emission factor = 487.0 gm/mi.
    Idling emission factor = 1,000.0 gm/hr
4 18-Wheelers Diesel Trucks, 5 mph, traveling emission factor = 47.5 gm/mi.

Idling emission factor = 94.6 gm/hr

The number of snowmobiles traveling on the express is always twice the number of snowmobiles traveling on the other lane based on a conservative estimate by NPS of the number of vehicles using the express lane at the West Entrance during the 2000-2001 winter season. In the previous example, there are a total of 900 snowmobiles on the roadway.

The snowmobiles were traveling in adjacent travel lanes. The snowcoaches and trucks were traveling on one lane.

The 10 gasoline snowcoaches were existing old snowcoaches with no emissions controls. (Bishop et al., 1999.)

The trucks are included because of deliveries made to the Yellowstone National Park that pass by the entrance and the CO monitoring station, even though they do not actually enter the park.

Scenario 1: 1997 fan-cooled Polaris 500cc 2-stroke engine using conventional gasoline fuel and tested in a laboratory in San Antonio, Texas. (Alternative A from FEIS)

Scenario 2: 2001 Polaris Trail Sport fan-cooled 550cc 2-stroke snowmobile using a 10 percent ethanol 90 percent gasoline blend fuel and tested in field conditions at Flagg Ranch, Wyoming. (This is the baseline for comparison.)

Scenario 3: CSC student modified 2-stroke engines using a 10 percent ethanol: 90 percent gasoline blend fuel and tested in field conditions at Flagg Ranch, Wyoming.

Scenario 4: CSC student modified 4-stroke engines using a 10 percent ethanol: 90 percent gasoline blend fuel and tested in field conditions at Flagg Ranch, Wyoming.

Snowcoach Alternative

Worse Case Morning Period 8:00 – 9:00 A.M.

120 Gasoline Snowcoaches, 10 mph; traveling emission factor = 109.9 gm/mi. (U.S. Dept. of the Interior, 1999).

These snowcoaches are assumed to be newer snowcoaches that meet emissions standards. Consequently the emissions factor used here is less than the emissions factor for the 10 older snowcoaches considered in the snowmobile alternatives. There are not sufficient numbers of snowcoaches available today for a fleet of 120, so additional new snowcoaches would have to be purchased if this alternative was selected.

A more complete description of the modeling assumptions is in Appendix A.

RESULTS AND DISCUSSION

The original 1999 modeling analysis indicated that the vehicle fleet comprising 900 snowmobiles (1997 model year) produced the highest 1-hour CO concentration, 42.2 parts per million (ppm) or 47.2 ppm including the 5.0 ppm background CO concentration. Without the background CO concentration, the source contributions by the three different types of vehicles were snowmobiles (96.0 percent), snowcoaches (4.0 percent), and diesel trucks (0.0 percent); the snowmobiles and snowcoaches contributed 40.5 and 1.7 ppm, respectively

The model estimated the highest 1-hour CO concentration from the snowcoach alternative, a fleet of 120 snowcoaches, was 1.1 ppm or 6.1 ppm with the background CO concentration. For comparison, the 1-hour National Ambient Air Quality Standard (NAAQS) and the Montana Ambient Air Quality Standard (MAAQS) are 35.0 and 23.0 ppm, respectively, which can not to be exceeded more than once a year.

Including the background CO concentration, the fleet of 900 snowmobiles (1997 model year) caused 25.9 and 89.0 percent greater CO concentrations than the NAAQS and MAAQS, respectively, thereby violating both standards. Corresponding percentages for the snowcoach fleet were 82.6 and 73.5 percent less than the federal and state standards, respectively.

These comparisons use the emissions data from the 1999 report. An additional comparison was done for the 1997 snowmobiles and is shown in

Table 1 as "1997 Snowmobile Industry." This comparison is made because DEQ was informed by industry that the CO emission factors for 5 and 10 mph used in the 1999 analysis needed to be changed to reflect the specific engine and power use at those speeds. These new industry numbers were applied to the 2001 baseline and CSC analysis. DEQ shows both the original 1999 emissions factors and the newer industry emissions factors for the 1997 snowmobiles. This allows a comparison to be made to the various snowmobile alternatives used in this analysis, and to compare back to the emissions factors used in the 1999 analysis.

The additional modeling analysis with both sets of emissions factors for the 1997 snowmobiles also shows what impact the new emissions factors would have had if they had been applied in the 1999 analysis. The results show some reduction in the atmospheric CO concentration, however, both the federal and state standards would still be violated. So, there is no impact on the conclusions reached in the 1999 report.

Travel speeds affect the amount of CO emitted (emission factor) from a vehicle exhaust. A CO emission factor (E_f) estimates the amount of carbon monoxide emitted from the vehicle's exhaust while moving (grams of CO per mile) or idling (grams of CO per hour). The snowmobiles traveled at three different speeds in the fore-mentioned analysis: 0 (idle), 5, and 10 miles per hour (mph). The highest amount of carbon monoxide is emitted during idling and decreases with increasing travel speed from 5 to 10 mph.

The 2001 Polaris fan-cooled 550cc control 2-stroke snowmobile was selected by the CSC Board of Directors as the typical touring sled snowmobile in the greater Yellowstone area. Emissions data from this snowmobile were used as the best estimate of what is available currently. Due to these reasons, this class of snowmobile was selected_the "baseline" for comparison to the other types of snowmobiles. This snowmobile was selected at random from the Flagg Ranch rental fleet. This fleet was calibrated to run rich (high CO) for reliability and durability in the altitude and temperature conditions.

Table 1 displays the emissions testing conditions (fuel type, ambient temperature, elevation, and environment), CO emission factors (E_f) for snowcoaches, and 2001 CSC and 1997 snowmobiles, travel speeds, and the percentage reduction (or increase) of the 2001 CSC and 1997 snowmobile emission factors relative to the 2001 2-stroke baseline emission factors. The relationships (ratios) between the 2001 CSC and 1997 snowmobiles to the 2001 2-stroke baseline emission factors are also provided in brackets. The HI refers to the highest level for all machines in that category while the LO refers to the lowest level for all machines in that category. Note that the units are different for the idle mode (grams per hour) and the other travel speeds (grams per mile).

Table 1. Emissions testing conditions (fuel type, ambient temperature, elevation, and environment), CO emission factors (E_f) for the various types of snowmobiles and travel speeds, and the percentage reduction (or increase) of the snowmobile and snowcoach emission factors relative to the 2001 2-stroke baseline emission factors. The relationships (ratios) between the snowmobiles to the 2001 2-stroke baseline emission factors are also provided in brackets. Shaded cells in table denote the reference snowmobile.

Snow-mobile Type	Fuel Type	Emis. Test Temp (F)	Emis. Test Elev. (meter; feet)	Emis. Test Env.	Idle CO Emission Factor (g/hr)* [ratio E_f to Baseline E_f]		Percentage Change Relative to the Baseline Idle E_f (%)		5 mph** CO Emission Factor (g/mi.)*** [ratio E_f to Baseline E_f]		Percentage Change Relative to the Baseline 5 mph E_f (%)		10 mph CO Emission Factor (g/mi.) [ratio E_f to Baseline E_f]		Percentage Change Relative to the Baseline 10 mph E_f (%)	
					LO	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
1997 Snow-mobile	Gas	60	184.6, 600	Lab	1000.0 [1.3]		25		800.0		99		395.0		96	
1997 Snow-mobile Industry	Gas				1000.0 [1.3]		25		111.0		94		224.0		94	
2001 2-Stroke Baseline	E-10	15 – 35	2,092; 6,800	Field	746.6		------		7.2		------		14.5		------	
2001 CSC New Tech. 2-Stroke	E-10	15 – 35	2,092; 6,800	Field	260.2 [0.3485]	2,135.0 [2.8596]	-187	65	0.4 [0.0556]	0.8 [0.1111]	- 1,700	- 800	0.9 [0.0621)	1.7 [0.1172)	- 1,511	- 753
2001 CSC New Tech. 4-Stroke	E-10	15 – 35	2,092; 6,800	Field	2.0 [0.0027]	697.0 [0.9336]	- 37,230	- 7	0.1 [0.0139]	18.0 [2.5000]	- 7,100	60	0.27 [0.0186)	36.0 [2.4828)	- 5,270	60
Snow-coach	Gas	22	2,012; 6,600	Field	N/A****		N/A		N/A		N/A		109.9		87	

* g/hr = grams per hour.
** mph = miles per hour.
*** g/mi. = grams per mile.
**** N/A = not available.

ɿs produced by the fleet in the scenario, and the percentages of the estimated CO concentrations to the 1-hour NAAQS and MAAQS
ↄO concentrations are given in brackets. The snowcoaches do not stop. Assumed that the number of snowmobiles traveling through
ʼ pass. The background CO concentration (5.0 ppm) is included.

Percentage (%)* NAAQS	Percentage (%)* MAAQS	New Tech. 2-Stroke Estimated CO Conc. (ppm) [% Contribution by Snowmobiles] LO	New Tech. 2-Stroke Estimated CO Conc. (ppm) [% Contribution by Snowmobiles] HI	Percentage (%) NAAQS LO | HI	Percentage (%) MAAQS LO | HI	New Tech. 4-Stroke Estimated CO Conc. (ppm) [% Contribution by Snowmobiles] LO	New Tech. 4-Stroke Estimated CO Conc. (ppm) [% Contribution by Snowmobiles] HI	Percentage (%) NAAQS LO | HI	Percentage (%) MAAQS LO | HI
			16.6 [46.4]	N/A | 47.4	N/A | 72.2				
			24.0 [64.2]	N/A | 68.6	N/A | 104.3				
			31.1 [72.4]	N/A | 88.9	N/A | 135.2				
			36.7 [79.8]	N/A | 104.9	N/A | 159.6				
			42.7 [84.3]	N/A | 122.0	N/A | 185.7				
58.6	89.1	11.6 [38.8]	45.0 [85.1]	33.1 | 128.6	50.4 | 195.7	8.9 [0.0]	20.3 [65.0]	25.4 | 58.0	38.7 | 88.3
59.7	90.9	11.7 [39.3]		33.4 | N/A**	50.9 | NA	8.9 [0.0]	20.8 [67.8]	25.4 | 59.4	38.7 | 90.4
60.6	92.2	11.7 [37.6]		33.4 | N/A	50.9 | NA	8.9 [0.0]	21.2 [68.4]	25.4 | 60.6	38.7 | 92.2
61.1	93.0	11.7 [37.6]		33.4 | N/A	50.9 | NA	8.9 [0.0]	21.5 [68.8]	25.4 | 61.4	38.7 | 93.5
61.4	93.5	11.7 [37.6]		33.4 | N/A	50.9 | NA	8.9 [0.0]	21.6 [69.0]	25.4 | 61.7	38.7 | 93.9
61.7	93.9	11.7 [37.6]		33.4 | N/A	50.9 | NA	8.9 [0.0]	22.0 [69.6]	25.4 | 62.9	38.7 | 95.7
62.0	94.3	11.7 [37.6]		33.4 | N/A	50.9 | NA	8.9 [0.0]	21.1 [69.7]	25.4 | 60.3	38.7 | 91.7

Based on the CO emission factors, the CSC new technology 2- and 4-stroke snowmobiles would produce significantly less CO, particularly from snowmobiles with the "low" range emission factors relative to the 2001 2-stroke baseline emissions factors. For the CSC 2-stroke clean snowmobiles with the low range of emission factors, CO emissions could be reduced from 180 to 1700 times with increasing speed. Corresponding values for the CSC 4-stroke snowmobiles could emit 37,000 to 5,200 times less CO emissions relative to the baseline.

The high range of emissions factors from the CSC 2-stroke snowmobiles could produce more CO during the idling phase relative to the 2001 2-stroke snowmobile, but CO emissions would be reduced 800 fold when traveling either 5 or 10 mph. Definitive estimates can not be established due to the wide range of student's ability to properly tune their engines. However, the amounts of CO emitted by the CSC new technology snowmobile exhaust would be considerably less than the 2001 2-stroke baseline snowmobiles.

There are several explanations for the differences in the CO emission factors between the baseline 1997 and 2001 2-stroke snowmobiles. Use of oxygenated fuels use by snowmobiles can reduced CO emissions by 9 to 38 percent (White et al., 1998c). Another difference in the 1997 and 2001 emissions factors was that the 1997 laboratory data were different than the field data as field conditions are usually not repeatable, and probably have a greater day-to-day variation with the 2-stroke engines than under the lab conditions.

The data on the 2001 baseline and CSC sleds were performed on a chassis dynamometer with a procedure that was developed for an engine dynamometer. Test results were close, but would not be expected to be exactly the same as the engine dynamometer tests. For example, the 2001 results now include any inconsistencies introduced by the continuously variable transmission (CVT) that will vary the throttle settings at low speeds (under 25 mph), and thus, vary the emissions factors in the transitional area between 0 to 25 mph. In other words, the emissions factor derived at a power setting for 15 mph, will be different if the engine increases power (from 1 mph) or decreases power (as from 30 mph). In these analyses, all data were run from higher to lower power levels according to the protocol.

The snowmobiles with their corresponding CO emission factors were entered into the model, CAL3QHC, to determine the highest estimated 1-hour CO concentration. The initial model run for all of the snowmobile types was 600/300. This scenario means a total 900 snowmobiles were traveling the roadway, 600 snowmobiles did not stop (express) and 300 snowmobiles had to stop. Depending on the type of snowmobile, the number of snowmobiles varied from 100 to 1200 for those traveling on the express lane. Corresponding numbers of snowmobiles traveling on the other lane that had to stop (to purchase a day pass) varied from 50 to 600. The determining factor was whether the estimated CO concentrations from the snowmobile exhaust violated a federal or state standard; if the concentration exceeded the standard, increasing the number of snowmobiles was pointless. Table 2 presents the number of snowmobiles, the highest modeled 1-hour CO concentrations produced from their vehicle emissions, and percentages of these CO concentrations to the NAAQS and MAAQS.

The air dispersion model calculates the CO concentrations at every designated point along both sides of the roadway. Changing the direction the wind is coming from determines which point has the highest 1-hour CO concentration. Under most wind directions, snowmobiles were responsible for the highest concentrations. However, snowcoaches were the primary contributor to total CO under certain wind directions. The only comparable CO emissions to the emissions from snowcoaches alone was from the CSC new technology 4-stroke snowmobiles (low range) where the model indicated that essentially only the snowcoaches contributed to the atmospheric carbon monoxide concentrations.

CONCLUSIONS AND RECOMMENDATIONS

From this analysis the following conclusions were developed:

The 2001 550cc snowmobile tested in field conditions using ethanol fuel performed significantly better than the 1997 500cc snowmobile using regular gasoline fuel. Since the testing conditions were different it is not possible to draw absolute conclusions for the improvements. It is likely that the improvements were due to a combination of efficiency improvements by industry, fuel type, cold temperature field-testing, and a change in the way the dynamometer testing was conducted.

The baseline 2001 snowmobile data were representative of actual operating conditions and will be a better comparison for alternatives developed in the Supplemental Environmental Impact Statement (SEIS).

The snowcoach alternative produced a lower peak 1-hour CO concentration than any number of the baseline 2001 snowmobiles evaluated.

New clean snowmobile technologies demonstrated at the Clean Snowmobile Challenge 2001 could significantly reduce carbon monoxide emissions from snowmobiles. These reductions are available from both two-stroke and four-stroke machines modified by university students, but not yet commercially available. The competition illustrated the potential of emissions reductions, however the machines were designed for trail riding and are not representative of the fuel range of commercially available snowmobiles.

Up to 750 snowmobiles with emissions similar to the **low** emissions range of CSC 2-stroke snowmobiles, using ethanol blend fuel, and with two-thirds using the express lanes, would produce a lower peak 1-hour CO concentration than the snowcoach alternative.

Ambient CO levels would be expected to exceed the MAAQS 1-hour CO standard (by 129 percent) with less than 150 snowmobiles having emissions similar to those estimated for the **high** range of CSC 4-stroke type snowmobiles. (This is based on using the snowcoach alternative from the first report estimating the highest 1-hour CO concentration at 1.1 ppm).

Up to 750 snowmobiles with emissions similar to those of the CSC 4-stroke snowmobiles with two-thirds using pre-paid passes would produce a lower peak 1-hour CO concentration than the snowcoach alternative.

However, the emissions results for the CSC snowmobiles are based on individually modified snowmobiles, not fleets. Whether the technologies applied to these machines can be reproduced on a mass production scale is unknown, but the competition did require the modifications to be cost effective and practical. The true test would be for a fleet composed of the CSC 2-stroke snowmobiles using the ethanol blend to be used in Yellowstone National Park for several winter seasons under "normal" maintenance and use.

Further air dispersion modeling using currently available industry developed four-stroke engines is needed to better determine the effects of new technologies on carbon monoxide emissions.

Recommendations

Additional information needs to be obtained on new technology snowmobiles from manufacturers, particularly the 4-stroke machines that are currently operating in Yellowstone National Park, Grand Teton National Park, and John D. Rockefeller Jr. Memorial Parkway. Modeling analysis should be completed with this industry information. The evaluation of the

Clean Snowmobile Challenge data shows what might occur in the future. However, information from the manufacturers on current production vehicles would be the best method to determine what emissions reductions are likely within the next few years.

Develop a process for student teams to better tune and adjust their competition snowmobiles to reduce the emissions variability. The large range of emissions, especially at idle, illustrates that more time and tuning is needed to eliminate the randomness of emissions.

Continue the use of ethanol fuels in snowmachines. This fuel reduces the carbon monoxide emissions without impact to the snowmobile operator.

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APPENDIX A. Snowmobile and Bombardier (snowcoach) Carbon Monoxide Emissions and Air Dispersion Modeling Assumptions.

Snowmobile:

Alternative A: Baseline Gasoline CO Emissions:

Vehicle Miles/Hour	Grams/Mile	Grams/Hour
0	NA [a]	1000
5	1741	NA
15	580	NA
25	348	NA
35	249	NA

[a] NA = not applicable.

Source: U.S. Department of the Interior. 1999, p. 27, White et al., 1998.

Calculation for 5 mph: The model, CAL3QHC, truncates all CO emission factors greater than 1,000 to 1,000 so the 5 mph emission factor became 1,000 grams per mile.

Calculation for 10.0 mph: Graphed the 4 points on graphing paper. Estimated a curvilinear line through all 4 points since it is well known that this relationship exists between CO emissions and with vehicle speed (mph). An 800 gm/mi. emission factor was approximated and used.

Snowcoach:

Bombardier High Altitude Light Duty Gasoline Truck for CO at 5.0 mph = 1,526.06 gm/mi., 25° F, 100% cold starts, calendar year = 1980 since the Bombardier that have no emission controls similar to pre-1970 V-8 and the tables do not precede 1980. Used maximum allowed CAL3QHC CO emission factor = 1,000.0 gm/mi. (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Table J-27). Idling for CO = 487.0 gm/hr winter conditions: 30° F, 13.0 psi RVP gasoline (Emission Facts: Idling Vehicle Emissions). Appendix J High Altitude not available for 25.0 mph, but have Tables J-29 and J-30 High Altitude for 19.6 and 35.0 mph, respectively. Averaged the data for the two types of Snowcoaches and prorated based on number of each type. 10 Bombardier; High Altitude, Light Duty Gasoline Truck for CO at 25 mph = 293.46 gm/mi. (19.6 mph) + 192.72 gm/mi. (35.0 mph) = 486.18/2 = 243.1 gm/mi., 25° F, 50% cold starts 50% stabilized 50% hot starts, calendar year = 1980. Gasoline Snowcoaches in Lanes 1 and 2 at 10 mph; traveling emission factor = 109.9 gm/mi. (DEIS p. 38). No table available for 15 miles per hour (MPH). Graphed 5.0, 10.0, 19.5 and 35.0 MPH, 25° F, 100% cold starts, calendar year = 1980, and approximated 15 MPH = 630 gm/mi. (Compilation of Air Pollutant Emission Factor – Volume II: Mobile Sources, Tables J-27 - 30).

Appendix B

Clean Snowmobile Challenge 2001

CO emissions factors	Idle CO Emission Factor (g/hr)	5 mph CO Emission Factor (g/mi.)	10 mph CO Emission Factor (g/mi.)	25 mph CO Emission Factor (g/mi.)	Additional Data mph (g/mi.)	mph (g/mi.)	mph (g/mi.)
					32.00	50.00	70.00 mph
Baseline	746.60	7.23	14.45	34.72	43.40	145.50	215.70
2001 Polaris Trail Sport 550cc on ethanol blend fuel							
CSC 2-Strokes					42.00	52.00	75.00 mph
MSU-Mankato	2135.00	0.43	0.85	2.13	3.57	44.54	326.07
					32.00	46.00	70.00 mph
Waterloo	260.20	0.83	1.65	4.13	5.28	74.09	250.56
Range 2-Strokes	260.00 - 2,135.00	0.40 - 0.80	0.90 - 1.70	2.10 - 4.10	for new technology 2-strokes w cat		
CSC 4-Strokes					22.00	35.00	55.00 mph
Buffalo	93.10	16.50	33.00	54.09	66.00	14.40	2.90
					21.00	36.00	60.00 mph
Idaho	697.00	18.00	36.00	70.80	71.00	70.00	123.00
					44.00	55.00	71.00 mph
Kettering	2.00	0.14	0.27	0.68	1.20	33.70	256.30
Range 4-Strokes	2.00 - 697.00	0.10 - 18.00	0.27 to 36.00	0.38 to 71.00	*for new technology 4-strokes		

*4-strokes emissions could have been improved 40 to 60 percent if tuned properly,

*and of these, only Kettering had an engine with OEM supplied catalyst and controls.

Wyoming and Colorado School of Mines were too underpowered.

Clarkson's entry had commercial reliability problems that would effect emissions.

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Electric Snowmobile Demonstration Status Report

Sn❄wLectric
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Introduction

Snowlectric has been engaged in a cooperative agreement with the National Parks Service/Yellowstone (NPS) for the past 18 months to explore the possibilities of an electric snow machine. NPS supplied Snowlectric with a Polaris Indy 500 snowmobile chassis, and this machine has successfully been converted to a fully electric-powered snowmobile. Snowlectric supplied all of the necessary operating components and labor. This report summarizes prototype testing and drive analysis.

Power Systems and Performance

Testing was performed at 48, 72, and 120 volts (V), as increased voltage requires less current to generate the same power. Since high current drain is one of the primary factors in reduced battery, motor and controller life, it was expected that higher system voltages should allow more power to be successfully drawn from the batteries. These concepts proved themselves, as progressions to higher voltage yielded both increased power and longer runs. Most of the testing was at 72 V, which yielded a typical run of about 5 miles at 25 mph. A top speed of 55 mph was achieved on asphalt. Acceleration was similar to a standard snowmobile. Hill performance on slopes of 6-8 percent was 20-30 mph, and 12 mph on a slope of 20 percent. At 120 V, the top speed was 35-40 mph. However, spring arrived before a good database could be developed at 120 V. The data suggests to us that 120 volts or greater will be the best choice for this machine.

Transmission

Two different transmission systems have been tested: a direct drive gear system that uses a poly belt, and a standard snowmobile clutch Continuously Variable Transmission (CVT).

The direct drive system has shown itself to be quieter and more efficient at cruising speed, but has undesirable compromises in gear choices as they relate to acceleration vs. cruising power requirements.

The existing CVT in snowmobiles has many advantages, primarily it's performance at a variety of speeds. The standard clutch was modified to operate within the general RPM range of the electric motor, but was not optimized, as the primary clutch will only close about half of what it should. The optimum combination of heavier weights and lighter springs, as well as the proper chain case ratio, should correctly tune the CVT to the range of electric motor operation, thus providing a noticeable increase in efficiency and top speed.

Limitations

One major problem with the current prototype is that it weighs about 900 pounds at 72 V. The recharge time is 4-5 hours. Furthermore, the combination of cold temperature and high discharge rate is a dual blow to the suitability and life of lead acid batteries.

Emissions

Zero.

Noise

As expected, this machine exhibits a huge advantage over conventional 2-stroke snowmobiles in the area of noise reduction. The data in the following table was collected under the severest possible conditions; a crusty, frozen snowmobile track with solid frozen surrounding snow. All data was collected at full throttle using the "A" scale weighting on the decibel meter. Distance was measured perpendicular to the path of the snowmobile for both (CVT and direct drive) types of transmissions.

Distance to Snowmobile (ft)	CVT noise dB	Direct drive noise dB
50	69	66
100	61	61
150	58	54

(In contrast, casual readings taken on 2-stroke snowmobiles in West Yellowstone registered from 80-85 decibels at 50 feet.)

There is also a noticeable difference in the nature of the noise created by an electric motor vs. a 2-stroke gasoline engine. The noise created by a 2-stroke engine is of a much higher frequency, which propagates through air better than lower frequencies. Electric motors are virtually silent. The majority of the noise that is created by the electric snowmobile is the inherent low frequency mechanical vibration created by the transmission, track, suspension, and skis. These low frequency noises are quickly dampened by the surrounding snow, and partially explain the rapid drop in noise level with decreasing distance observed in the above figure. Packed powder or light snow conditions should yield significantly quieter readings.

Summary and Proposal

The intent of this project was to demonstrate an electric snowmobile that used a standard motor and energy supply, and to collect baseline data to prove concept viability. All testing to this point has been executed using standard electric vehicle (EV) technology, transmissions modified with standard parts, and lead-acid batteries. Appropriate technologies for a motor and transmission have been identified, but lead acid batteries are not a good choice due to their poor cold weather discharge, low capacity performance, heavy weight, and relatively meager energy density. The next planned battery step was to upgrade to Nickel Metal-Hydride (NiMh) batteries, which have improved cold weather performance, lighter weight, and improved capacity. The advanced step was to explore the use of fuel cells, which are the most attractive option. Fortunately, fuel cell technology has increased much faster than anticipated, and small vehicle transportation fuel cells are now reportedly available for prototype demonstration. This exciting information leads the scope of the project past NiMh batteries and directly to fuel cells. Fuel cells provide much higher energy density, immediate refill, longer range, and greatly decreased weight. It is anticipated that a 20 Kilowatt fuel cell and electric motor package installed on a standard snowmobile chassis could yield a finished machine weight under 500 pounds, with an expected range of 25-50 miles with speed and performance similar to current trail snowmobiles.

Proposed Objectives

1. A consortium of NPS, DEQ/EPA, DOE, DOD and fuel cell manufacturers should combine their resources to install fuel cells on either a conversion model snowmobile or "ground-up" prototype. The cold temperature, high drain conditions under which a snowmobile operates will provide an excellent testing platform to demonstrate the superior operating capabilities of a fuel cell. Snowlectric is offering to be the organizer and coordinator of such a consortium.
2. Rebuild the current snowmobile chassis to 120 volts lead acid system with and on-board charger and current converters. This option is simply a short term, economical solution that would continue to provide electric snowmobile performance data.

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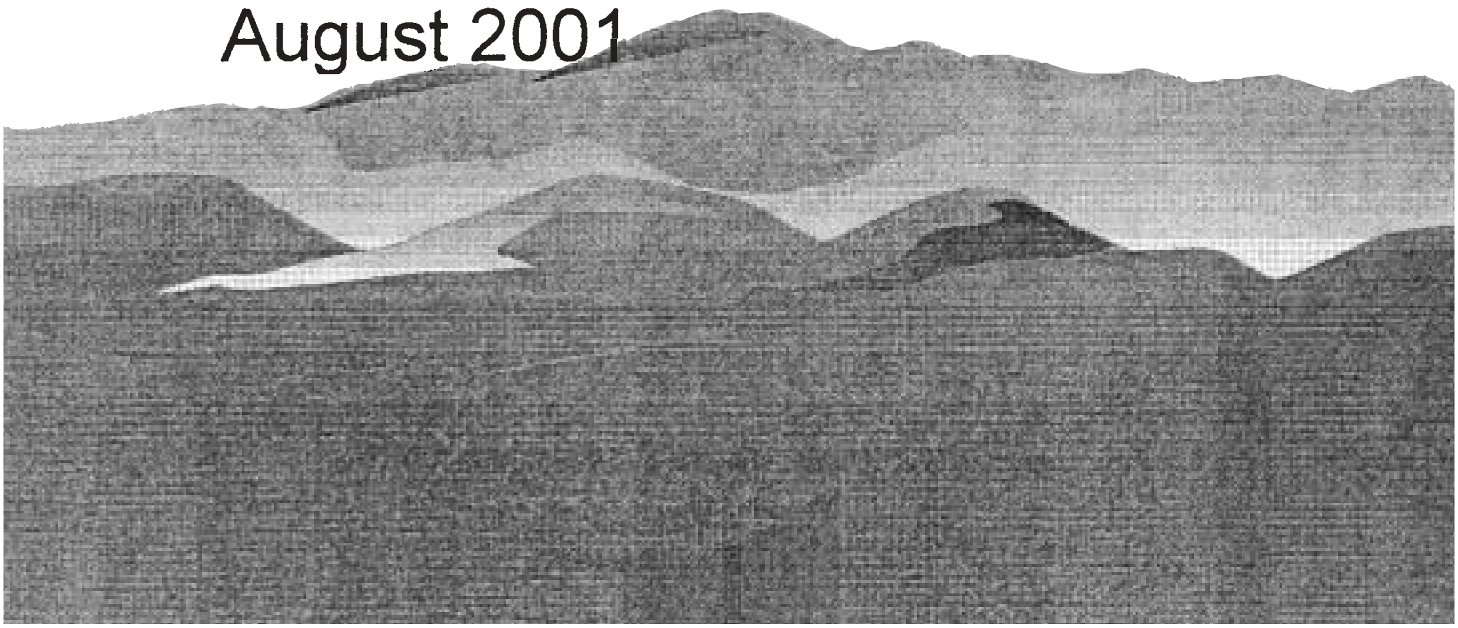
Economic Importance of the Winter Season to Park County, Wyoming

by: David T. Taylor

August 2001



The University of Wyoming and the United States Department of Agriculture cooperating.
The University is an equal opportunity/affirmative action institution.

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INTRODUCTION

The winter season is an important time of year for the Park County economy. While the visitor volume and total visitor expenditures are lower than in the summer months, winter visitors are important because their expenditures help sustain local businesses between summer season peaks. The winter season is also important because it provides recreation opportunities for county residents. Much of the winter recreation enjoyed by both residents and nonresidents in Park County is associated with activities within Yellowstone National Park. Activities such as back-country skiing, ski mountaineering, snowshoeing, cross-country skiing, dog sledding, snowmobiling, wildlife watching, ice climbing, and sightseeing draw both visiting tourists and local residents to Yellowstone National Park (YNP).

Tourism is an important part of the Park County economy. Based on lodging tax collections it is estimated that visitor expenditures in Park County totaled about $70 million in 2000. State data indicates that lodging tax collections in Park County increased by over 9 percent between 1998 and 2000. However, county lodging tax collections for the winter months increased by over 30 percent between 1998 and 2000. While total employment increased by less than 3 percent between 1995 and 1999, service sector employment in Park County during the winter months increased by 15 percent. These numbers indicate that winter season tourism is a growing part of the Park County economy.

This report is not intended to provide a comprehensive evaluation of the importance of the winter visitors in the Park County economy. Rather it is intended to provide information on what is currently known. More in-depth information about winter visitors to the area will no doubt improve the analysis when it becomes available.

PROCEDURES

Information for this report was gathered from a variety of secondary data sources including Wyoming State government agencies and reports, University of Wyoming studies, consultant reports, and Federal agency reports. Information was also obtained from the business community in Park County and the Cody Country Chamber of Commerce.

EXECUTIVE SUMMARY

- On average, over 85 percent of total lodging taxes in Park County were collected during the five month period from June through October. Although lower than during the summer season, lodging tax collections during the peak winter recreation month (January) averaged over 81 percent higher than collections during the fall low point (November).

- On average, peak total employment for Park County in July was nearly 33 percent higher than the low point in January. Peak employment for the service sector in July averaged 82 percent higher than the low point in January. A reduction in winter visitors, would reduce winter employment in Park County even more.

- Thirty percent of the Park County businesses responding to a survey indicated that they had direct sales to winter visitors to Yellowstone National Park. These businesses indicated that sales to YNP winter visitors represented nearly 80 percent of their total winter sales.

- Average daily expenditures by nonresident snowmobilers in Wyoming were $142 per person. By comparison, average daily expenditures by general winter visitors were $73 per person and average daily expenditures by general summer visitors were $63 per person. Due to their higher expenditures, snowmobile visitors have a greater economic impact per visitor day than many other types of visitors to the state.

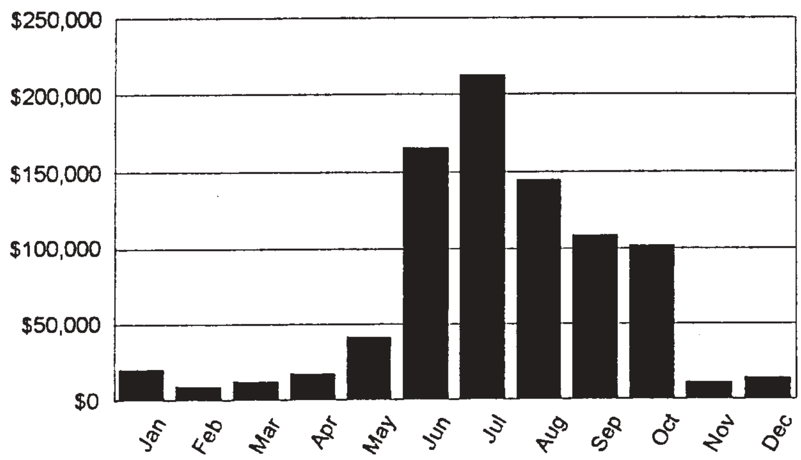
- The 1993-95 Wyoming Snowmobile Assessment estimated that nonresident snowmobilers spend $109 million annually in Wyoming. These expenditures resulted in $40 million in personal income and supported the equivalent of 3,063 full-time jobs for state residence. Nonresident snowmobilers expenditures also generated $5 million in tax revenue for state and local governments in Wyoming. Park County is an important site for snowmobiling in Wyoming.

- It is estimated that YNP winter visitors spent $5.1 million in Park County in 1998. These expenditures resulted in $1.8 million in personal income and supported the equivalent of 467 jobs during the winter season for Park County residents. YNP winter visitor expenditures also generated $306,800 in tax revenue for state and local governments in Wyoming. YNP winter visitor expenditures represent about 90 percent of total winter visitor expenditures in Park County. Elimination of winter access to YNP could represent a loss of employment equivalent to over 20 percent of winter service sector employment in Park County.

- Participating in winter recreation activities is important to Park County residents. The net economic value of participating in selected winter recreation activities for Park County residents was $3.9 million in 2000. Snowmobiling represented 69 percent of this total.

PARK COUNTY MONTHLY LODGING TAX COLLECTIONS

Figure 1.
Park County Average Monthly Lodging Tax, 1997-2001



Monthly lodging tax data for Park County was obtained from the Wyoming Department of Revenue's website (Table 1). The data was lagged two months to reflect delays in reporting. Figure 1 represents the monthly averages for the period May 1997 through March 2001. In FY97 the Wyoming Department of Revenue changed computer systems making monthly comparisons with previous data unreliable.

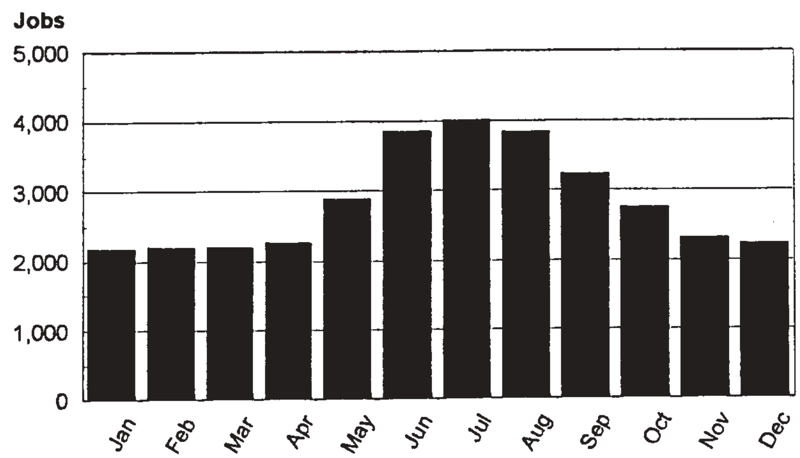
The lodging tax data indicates the seasonal nature of the tourism industry in Park County. On average, over 85 percent of total lodging tax collections occurred between June and October, with the remaining seven months accounting for less than 15 percent. Although lodging tax collections indicate lower winter visitor expenditures, these expenditures are still important to tourism businesses in Park County. Winter visitor expenditures help sustain many county tourism business financially between the summer season peaks.

The lodging tax data indicates that tourism is growing in Park County with total collections increasing by over 9 percent between 1998 and 2000. However, county lodging tax collections for the winter months (Dec., Jan., Feb., and Mar.) have increased by over 30 percent between 1998 and 2000.

Park County lodging tax figures include collections from lodging facilities in the northern part of Yellowstone National Park (Mammoth, Canyon, Fishing Bridge, and Roosevelt Lodge). During the winter season only the lodging facility at Mammoth is open.

PARK COUNTY MONTHLY EMPLOYMENT

Figure 2.
Average Park County Service Sector Monthly Employment, 1995-1999

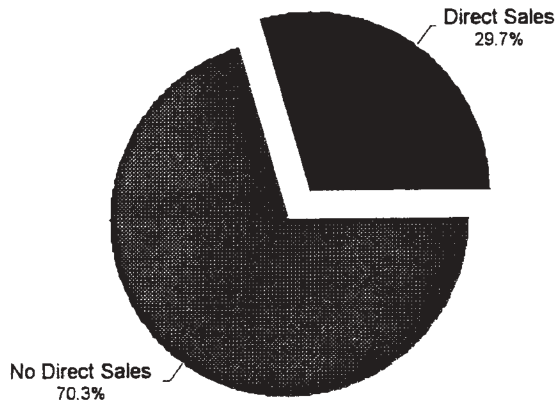


Monthly employment data for Park County was obtained from the Wyoming Department of Employment (Table 2). These data represents employment covered by unemployment insurance. Self-employed jobs are not included. Figure 2 summarizes average monthly service sector employment for Park County for the period 1995 through 1999.

The employment data indicates that employment in Park County is also seasonal in nature, peaking during the summer tourism season and then declining during the off-season. On average, employment during the peak in July has been nearly 33 percent higher than the low point in January. This trend is especially apparent in the service sector where peak employment in July has averaged over 82 percent higher than the low point in January (Figure 2).

The seasonal nature of employment in Park County makes expenditures by winter visitors important to the local economy. Since these expenditures occur during a slow time of the year they help sustain the local economy between the peak seasons. Without winter visitors, employment in Park County would be even lower during the winter months. Also, while total covered employment for Park County increased by less than 3 percent between 1995 and 1999, service sector employment during the winter season (Dec, Jan., Feb., and Mar.) increased by nearly 15 percent.

Figure 3.
Businesses with Direct Sales to YNP Winter Visitors



In March of 1999 the Cody Country Chamber of Commerce conducted a survey of Park County business to collect data on sales to Yellowstone National Park (YNP) winter visitors. The survey results were complied at the University of Wyoming by the Wyoming Cooperative Extension Service.

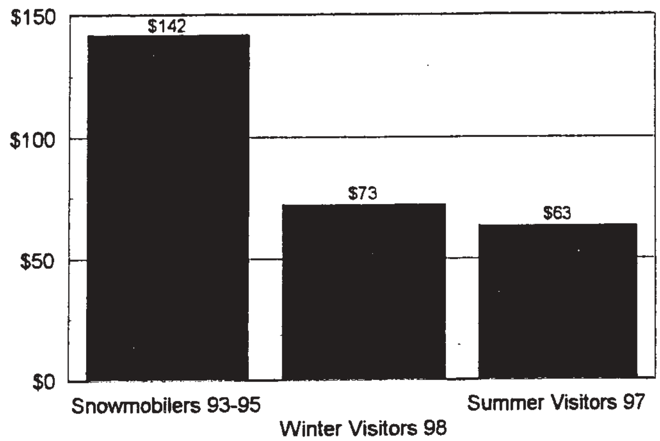
About 30 percent of the businesses responding to the survey indicted that they had direct sales to YNP winter visitors. For businesses with direct sales, YNP winter visitor expenditures represented nearly 80 percent of their total winter sales.

About 60 percent of the businesses with direct sales indicated that they would have to layoff employees if YNP prohibited winter visitation. Fifty percent of these businesses indicated that they would attempt to seek alternative sources of revenue. Thirty percent of these businesses indicated that they would close the business in the winter. Twenty-five percent of these businesses indicated that they would reduce non-pay-roll expenses. Ten percent indicated that prohibiting winter visitors would have other effects on their business.

The survey results did not consider the secondary economic effects associated with the loss of YNP winter visitor expenditures in Park County.

COMPARISON OF VISITOR EXPENDITURES

Figure 4.
Average Daily Expenditures Per Person for Wyoming



The University of Wyoming conducted an assessment of the economic importance of snowmobiling in Wyoming for the Wyoming Division of State Parks and Historical Sites based on data from the 1993-94 and 1994-95 winter seasons. This study focused on snowmobilers utilizing state maintained trails. Annually, Morey & Associates, Inc. conducts winter and summer visitor surveys for the State of Wyoming. Figure 4 compares the average daily per person visitor expenditure estimates derived from these studies. Unfortunately, none of the studies contains information specific to Park County or winter visitation to YNP.

Average visitor expenditures for nonresident snowmobilers were nearly twice that for general winter visitors and more than twice that for general summer visitors. This indicates that nonresident snowmobilers are part of the upper end of visitors to Wyoming in terms of expenditures. Their higher expenditure level means that snowmobile visitors have a relatively greater economic impact per visitor day on the Wyoming economy than other general types of visitors to the state.

ECONOMIC IMPACT OF SNOWMOBILING TO WYOMING

Figure 5.
Economic Impact of Snowmobiling to Wyoming

Direct Expenditures	$109 Million
Total Economic Activity	$189 Million
Personal Income	$40 Million
Employment	3,063 Jobs
Tax Revenue	$5 Million

The University of Wyoming's 1993-1995 Wyoming Snowmobile Assessment estimated the total economic impact of snowmobiling on the state's economy. The study focused on snowmobilers utilizing state maintained trails and did not include snowmobiling in YNP. The study also did not contain any information specific to Park County, however Park County is an important site for snowmobiling in Wyoming. Figure 5 summarizes the results of this study.

The study estimated that nonresident snowmobilers spent $109 million annually in Wyoming. Considering the "multiplier effect", this spending generated $189 million in total economic activity in the state. This economic activity resulted in $40 million in personal income and supported the equivalent of 3,063 full-time jobs for residents. This economic activity also generated $5 million in tax revenue for state and local governments in the form of gas tax, registration fees, and sale tax collections.

It is estimated that nonresident visitors represented about one-half of total snowmobile user days in Wyoming in 1994.

ECONOMIC IMPACT OF YNP WINTER VISITORS ON PARK COUNTY

Figure 6.
Economic Impact of YNP Winter Visitors on Park County

Direct Expenditures	$5.1 Million
Total Economic Activity	$8.7 Million
Personal Income	$1.8 Million
Employment	467 Jobs
Tax Revenue	$306.8 Thousand

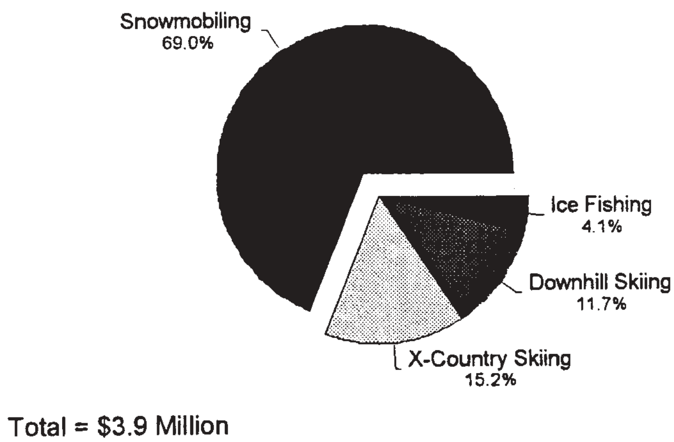
Total winter visitor expenditures in Park County were estimated using total lodging tax collections for December 1997- March 1998 (see Table 3). YNP winter visitor expenditures in Park County were estimated from an analysis by the Cody Country Chamber of Commerce for 1993-96. The Chamber analysis was based on the YNP Winter Travel Data Report and the YNP/University of Idaho Visitor Services Project Report 75. The Chamber estimates were updated to 1998 based on changes in average daily room rates for Wyoming between 1993 and 1998 (Table 3). The economic impact of YNP winter visitor expenditures was estimated using an input-output model developed for Park County by the Wyoming Cooperative Extension Service at the University of Wyoming.

Based on the above methodology it is estimated that winter visitors spent a total of $5.7 million in the Park County economy during the 1997-98 winter season. YNP winter visitor expenditures represented $5.1 million or 90 percent of the total. Considering the "multiplier effect", the $5.1 million in YNP winter visitor expenditures generated $8.7 million in total economic activity in the county. This economic activity resulted in $1.8 million in personal income for residents and supported 467 jobs during the winter season. The economic activity associated with YNP winter visitors also generated $306,800 in tax revenue for state and local governments in Wyoming in the form of sales, gas, and lodging taxes.

Because winter visitation is important part to Park County, the loss of winter access to YNP would have a serious effect on the local economy. Elimination of winter access to YNP could represent a loss of employment equivalent to over 20 percent of winter service sector employment in Park County.

VALUE OF WINTER RECREATION PARTICIPATION TO PARK COUNTY RESIDENTS

Figure 7.
Net Economic Value of Winter Recreation to Park County Residents, 2000



Winter recreation is important to Park County not only because it attracts visitor expenditures but also because it provides recreation opportunities for county residents. As such it is part of the quality of life associated with living in Park County. Winter recreation has an economic value to Park County residents through the enjoyment of recreation activities that they participate in during the winter season. The 1990 Wyoming State Comprehensive Outdoor Recreation Plan (SCORP) provides information on the participation rates and average number of trips by Park County residents for selected winter recreation activities. This data was applied to the 2000 population figures for Park County to estimate the current number of participants and their total trips. Information from a U.S. Forest Service on net economic values for recreation was then used to estimate the total net economic value of participation for selected winter recreation activities to Park County residents (see Table 4).

Figure 7 summarizes the net economic value of winter recreation participation for Park County residents. The SCORP data indicates that about 10 percent of Park County residents snowmobile. This compares to 14 percent who cross-country ski, 12 percent who downhill ski, and 4 percent who ice fish. The average number of trips per participant for snowmobiling (15.2 trips) was significantly higher than for other winter recreation activities. Park County residents were estimated to have made a total of over 80,600 winter recreation trips in 2000. Of this total nearly one-half were associated with snowmobiling. The net economic value of snowmobiling was also significantly higher than for other winter recreation activities. The total net economic value of winter recreation to Park County residents was estimated to have been $3.9 million in 2000. Snowmobiling represented nearly 70 percent of this total.

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TABLES

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Table 1. Monthly Lodging Tax Distributions for Park County, 1997-2001

Month (1)	1997 (2)	1998	1999	2000	2001	Average	Percent
January		$13,700	$32,793	$20,408	$15,663	$20,641	2.4%
February		$12,992	$7,842	$6,590	$11,162	$9,647	1.1%
March		$8,258	$15,000	$16,862	$10,557	$12,669	1.5%
April		$14,464	$18,834	$11,857	$24,531	$17,422	2.0%
May	$37,095	$51,312	$40,527	$39,565		$42,125	4.9%
June	$127,049	$192,502	$140,127	$204,238		$165,979	19.2%
July	$206,598	$199,610	$129,758	$315,518		$212,871	24.7%
August	$178,238	$191,946	$93,268	$115,878		$144,833	16.8%
September	$107,253	$112,240	$74,436	$141,451		$108,845	12.6%
October	$37,945	$27,226	$320,832	$22,971		$102,244	11.8%
November	$8,057	$9,815	$16,802	$10,759		$11,358	1.3%
December	$15,465	$12,384	$11,916	$17,900		$14,416	1.7%
Total		$846,449	$902,135	$923,997		$863,049	100.0%

(1) Lagged two months to reflect delays in reporting.
(2) In FY97 the Wyoming Department of Revenue changed computers systems making monthly comparisons with previous years unreliable

Source: Wyoming Department of Revenue

Table 2. Monthly Employment for Park County, 1995-1999

Month	1995 Total	1996 Total	1997 Total	1998 Total	1999 Total	Average
January	10,196	10,058	10,023	10,286	10,480	10,209
February	10,259	10,191	9,945	10,245	10,577	10,243
March	10,295	10,153	10,183	10,318	10,699	10,330
April	10,688	10,606	10,425	10,660	10,839	10,644
May	11,539	11,486	11,574	12,076	12,187	11,772
June	13,279	13,193	13,467	13,401	13,795	13,427
July	13,458	13,582	13,713	13,428	13,635	13,563
August	13,128	13,443	13,489	13,222	13,324	13,321
September	12,385	12,583	12,437	12,526	12,553	12,497
October	11,479	11,436	11,545	11,697	11,953	11,622
November	10,735	10,504	10,645	10,974	11,129	10,797
December	10,667	10,302	10,569	10,770	10,798	10,621
Average	11,509	11,461	11,501	11,634	11,831	11,587

Month	1995 Service	1996 Service	1997 Service	1998 Service	1999 Service	Average
January	2,094	2,065	2,217	2,238	2,390	2,201
February	2,136	2,164	2,170	2,241	2,406	2,223
March	2,042	2,151	2,217	2,242	2,414	2,213
April	2,127	2,147	2,281	2,347	2,444	2,269
May	2,755	2,684	2,760	3,089	3,165	2,891
June	3,640	3,640	3,729	4,011	4,258	3,856
July	3,905	3,970	4,007	4,017	4,154	4,011
August	3,721	3,820	3,820	3,926	3,914	3,840
September	3,009	3,017	3,264	3,443	3,463	3,239
October	2,630	2,555	2,737	2,918	2,989	2,766
November	2,189	2,188	2,280	2,484	2,477	2,324
December	2,081	2,097	2,293	2,381	2,370	2,244
Average	2,694	2,708	2,815	2,945	3,037	2,840

Source: Wyoming Department of Employment

Table 3. Estimated Winter Visitor Expenditures for Park County, 1997-98

Total Winter Visitors Lodging Tax Collections (Dec97 - Mar98) (1)		$50,415
Lodging Tax Rate	(/)	4.0%
Winter Visitor Lodging Expenditures		$1,260,375
Percent of Total Expenditures for Lodging (2)	(/)	21.9%
Total Winter Visitor Expenditures		$5,744,965

Distribution of Winter Visitor Expenditures (2)

Accomodations	$1,260,375
Restuarants	$1,143,131
Groceries	$175,866
Entainment/Attractions	$498,288
Outfitter/Guides	$117,244
Shopping	$2,022,462
Gas	$439,666
Car Rentals	$87,933
Total	$5,744,965

Average Daily Room Rate for Other Wyoming - Excluding Jackson (3)

	1993 Season	1994 Season	1995 Season	1996 Season	1993-96 Average	1998 Season	Change 1993-96 Ave vs 1998
December	$36.48	$38.37	$39.00	$39.13	$38.25	$41.60	
January	$37.05	$38.47	$40.02	$39.17	$38.68	$41.03	
Februay	$37.34	$38.51	$40.73	$39.91	$39.12	$43.41	
March	$38.15	$39.28	$41.73	$40.91	$40.02	$42.94	
Winter Season Average					$39.02	$42.25	108.3%

Annual YNP Winter Visitor Expenditures - Park County, 1993-96 (4)	$4,736,941
Adjustment to 1998	108.3%
YNP Winter Visitor Expenditures - Park County, 1998	$5,129,024

Source: (1) Wyoming Division of Economic Analysis, Department of Administration and Information
(2) Morey & Associates, Inc., Winter Visitor Survey - 1998
(3) Wyoming Lodging and Restaurant Association, Rocky Mountain Lodging Report
(4) Cody Country Chamber of Commerce

Table 4. Winter Recreation Activities for Park County Residents

Activity	(1) 1990 Participation Rate (1)	(1) Average Trips Per Year (1)	(2) 2000 Population	Total County Participants	Total Trips	(3) Net Economic Value Per Day	Total Net Economic Value*
Snowmobiling	9.9%	15.20	25,786	2,553	38,803	$69.97	$2,715,030
X-Country Skiing	13.9%	6.69	25,786	3,584	23,979	$24.90	$597,069
Downhill Skiing	11.9%	4.55	25,786	3,069	13,962	$33.02	$461,020
Ice Fishing	4.0%	3.80	25,786	1,031	3,919	$40.82	$159,993
Total					80,663		$3,933,111

* Note: Assumes an average of one day per trip. Also net economic values for fishing were used for ice fishing.

Source: (1) Wyoming State Comprehensive Outdoor Recreation Plan, 1990
(2) U.S. Department of Commerce, March 1999
(3) U.S. Forest Service, Intermountain Region, 1999